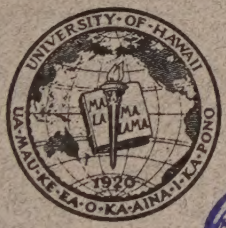
HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

Under the joint supervision of the
UNIVERSITY OF HAWAII
and the
UNITED STATES DEPARTMENT OF AGRICULTURE

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION

1937



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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU

(Under the joint supervision of the United States Department of Agriculture, Office of Experiment Stations, and the University of Hawaii)

JAMES T. JARDINE, *Chief, Office of Experiment Stations*
D. L. CRAWFORD, *President, University of Hawaii*

STATION STAFF AS OF JUNE 30, 1937

ADMINISTRATIVE

O. C. Magistad, Ph.D., *Director*
H. K. Hee, *Jr. Adm. Assistant*

AGRONOMY

J. C. Ripperton, M.S. ..... *Agronomist*
J. M. Westgate, M.S. ..... *Consultant in Tropical Agriculture*
L. D. Whitney, B.S. ..... *Asst. Agronomist*
F. A. I. Bowers, B.S. ..... *Prin. Agr. Aide*
A W. Burt, N.D.D. ..... *Prin. Agr. Aide*
E. Y. Hosaka, M.S. ..... *Asst. Biol. Aide*
M. Takahashi, M.S. ..... *Asst. in Agronomy*
E. K. Akamine, B.S. ..... *Asst. in Agriculture*

ANIMAL HUSBANDRY

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S. H. Work, Ph.D. ..... *Assoc. Animal Husbandman*
G. W. H. Goo, B.S. ..... *Assist. in Animal Husbandry*
C. I. Maruyama, B.S. ..... *Farm Supt.*

BACTERIOLOGY, PATHOLOGY AND HISTOLOGY

O. N. Allen, Ph.D. ..... *Collaborator in Bacteriology*
G. K. Parris, Ph.D. ..... *Assoc. Plant Pathologist*
Kazuo Kikuta, B.S. ..... *Under Scientific Helper*

CHEMISTRY AND SOILS

O. C. Magistad, Ph.D. ..... *Prin. Chemist*
E. M. Bilger, Ph.D. ..... *Collaborator in Chemistry*
L. A. Dean, Ph.D. ..... *Asst. Chemist*
R. R. Thompson, B. S. ..... *Sci. Aide*
E. T. Fukunaga, M.S. ..... *Asst. in Agr. Chemistry*

FOODS AND NUTRITION

Carey D. Miller, M.S. ..... *Assoc. Prof. of Foods and Nutrition*
N. P. Larsen, M.D. ..... *Collaborator*
Martha Potgieter, Ph.D. ..... *Assoc. Chemist*

HORTICULTURE

J. H. Beaumont, Ph.D. ..... *Principal Horticulturist*
G. W. Groff, M.S. ..... *Collaborator in Horticulture*
W. W. Jones, Ph.D. ..... *Asst. Physiologist*
J. E. Welch, M.S. ..... *Jr. Olericulturist*
R. H. Moltzau ..... *Prin. Agr. Aide*
J. C. Thompson, B.S. ..... *Prin. Sci. Aide*
W. B. Storey, B.S. ..... *Biol. Aide*

IRRIGATION

H. A. Wadsworth, B.S. ..... *Irrigation Engineer and Soil Physicist*

PARASITOLOGY AND ZOOLOGY

J. E. Alicata,[1] Ph.D. ..... *Parasitologist*
C. J. Hamre, Ph.D. ..... *Zoologist and Histologist*
H. G. Hansen[2] ..... *District Agent*
H. J. Spencer, B.A. ..... *Asst. Biologist*
J. S. Caceres[1] ..... *Collaborator*

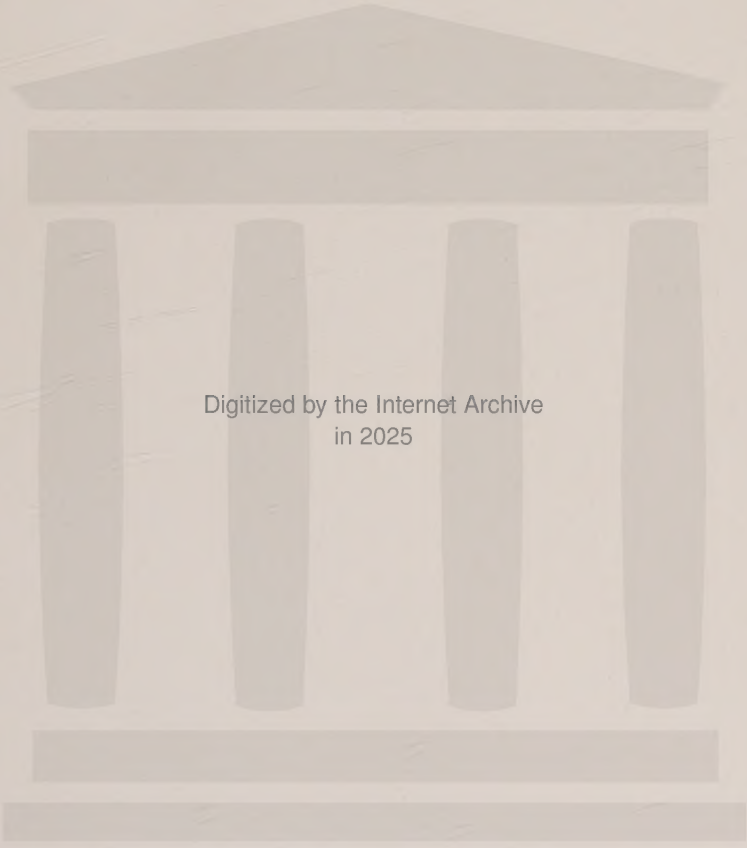
POULTRY

C. M. Bice, B.S. ..... *Poultry Husbandman*
F. L. Brown ..... *Asst. Agr. Aide*

BRANCH STATIONS

R. K. Pahau, B.S. ..... *Supt. Kona Branch Station*
R. A. Lyman, B.S. ..... *Supt. Haleakala Branch Station*

[1] In cooperation with Territorial Board of Health.
[2] In cooperation with United States Department of Agriculture, Bureau of Biological Survey.



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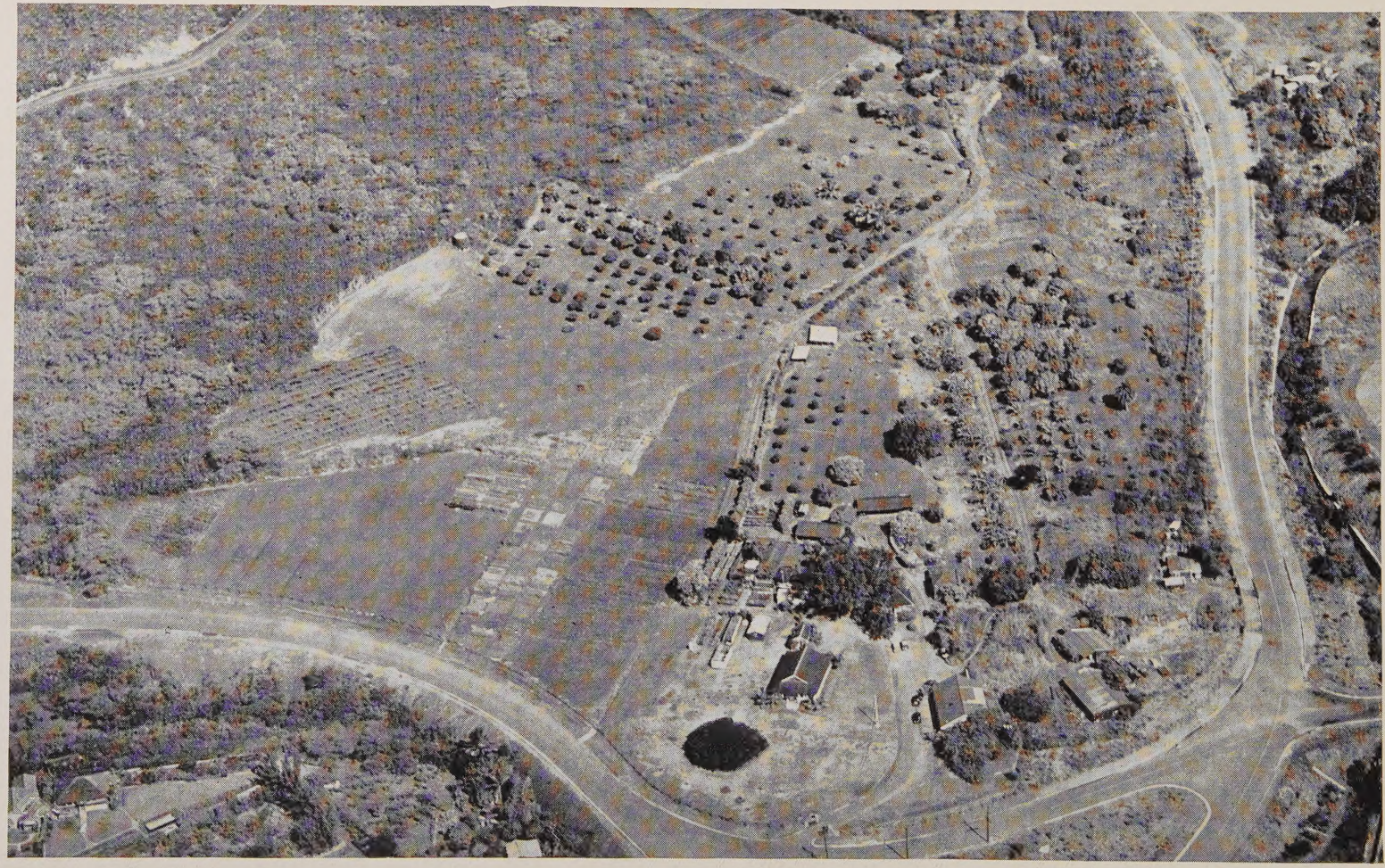

The Pensacola Street branch of the Hawaii Agricultural Experiment Station as seen from the air. (Photo by 11th Photo Section, A.C., U.S.A.)

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Honolulu, Hawaii 1937

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INTRODUCTION

During the fiscal year 1937, diversified agriculture in Hawaii made notable progress. The maritime strike, lasting from October 26 to February 6, was a great factor in stressing the importance of producing locally a larger share of the foodstuffs of the Territory. During this period only a few shipments of food were received from continental United States, and those few were from east coast ports. Other necessary food arrived, usually with payment of duty, from foreign countries such as Australia, Canada, Japan, and New Zealand. In addition to a shortage of foods for human consumption, a dearth of cattle and poultry feeds developed. A critical examination of the Territory's food economy bared the necessity for augmenting food production in Hawaii by a coordinated approach, including availability of land, water, and labor; experimental work with crop varieties, cultural methods, disease combat, and marketing; and educational work on maximum utilization.

Increasing financial returns from sugar and pineapple production in Hawaii, together with an upward trend in sugar quotas, have made it more difficult for other food crops to compete for land and labor. Notwithstanding this severe competition, it appears that there is a decided possibility of industrial development of the following crops: Asparagus, the macadamia nut, papayas, potatoes, taro, and tomatoes. Growing of potatoes for Territorial consumption and for winter marketing on the Pacific coast is a well-launched industry, with sales of about $350,000 during the past year. Asparagus is also profitable as a crop to be marketed on the mainland during the off-season. Tomatoes can be grown locally with profit, especially during the winter months when the normal supply comes from Mexico. Papayas and macadamia nuts are processed locally with ever increasing sales, while a new company has been established to make taro products such as taro flour, pancake flour, and a beverage base resembling cocomalt. These hopeful infant industries still have their infant ailments and need scientific and financial support at crucial periods.

The development of a strong station staff during the past two years is having its effect on diversified farming in still another way. Many local young men, working as assistants in the station, have become skilled in the practice of these new industries and, as a result, have received good commercial positions or have gone into such businesses on their own. The station staff has also made possible greater formal instruction in agriculture, and university students can now become better trained in agricultural fields.

Marked fluctuations in the station budget make it extremely difficult to retain a competent staff. Without assurance of a permanent position, which cannot be given under the present fiscal conditions, staff members resign to take other positions as they become available, often leaving a particular piece of work only partly completed.

Agricultural research is of little value if the results are not made known to the farmers of the Territory. A strengthening of the Agricultural Extension Service and fine cooperation with that body have helped bridge the gap between the research staff and the farmer. During the year the station has continued, with the Agricultural Extension Service, to prepare weekly radio talks.

NEEDS OF THE STATION

The merger of the Federal Experiment Station and the University Experiment Station, with provisions for gradually increasing appropriations through Hatch, Adams, Purnell, and Bankhead-Jones funds to offset decreasing direct appropriations to the Federal station, is now nearly consummated. For the year 1937-38, the direct appropriation to the Federal station is $2,066, and this is the final year for receiving such an appropriation. The merger agreement which, in 1938-39, will result in a wholly Territorial station similar to the State agricultural experiment stations, was approved.

The station, on September 1, 1937, acquired Poamoho Farm, between Wahiawa and Waialua, which will become the experimental grounds for plant investigations, primarily in horticulture and agronomy. With the acquisition of this farm and additional land at Kona, land requirements are satisfied. It is now our problem to obtain sufficient funds to develop these new areas with irrigation systems, roads, and buildings.

Last spring extension of the type of food processing investigations previously made on taro to such crops and products as papaya juice, passion fruit juice, canned litchi, and canned mango was contemplated, but with the resignation of G. J. Ley as chemical engineer in charge of the project steps had to be taken to secure a successor and suitable laboratory space and equipment. Failure of Congress to approve the previously authorized increase in Purnell funds to the station made it impossible to go forward with this work. It seems highly probable that a small but satisfactory industry along these lines can become established, and funds for such research work are highly desirable.

The station continues to be embarrassed in the matter of buildings and laboratory facilities, rented buildings being used for work on rats and taro. Erection of wings to the agricultural building will assist but not entirely alleviate this demand, particularly if the Federal buildings at Pensacola should become unavailable.

REPORT OF DEPARTMENTS

AGRONOMY

PASTURE INVESTIGATIONS

Vegetative Survey of Hawaiian Ranges

A plant survey of the principal ranches of the Territory was completed during the year. This included a total of 39 ranches on Hawaii, Maui, Molokai, Oahu, and Kauai, as well as many homesteads and small holdings. The primary purpose of the survey was to list all of the species of grasses, legumes, and miscellaneous plants which are of economic importance to the range industry. The different types of plant associations were mapped and the principal pasture areas classified.

Many new species have been added to the station's herbarium, which now comprises a total of 150 grasses, 25 legumes, and 200 miscellaneous plants growing in Hawaiian pastures. The most important of these are being described and illustrated for ultimate publication as a pasture handbook of Hawaii.

The ranchers showed a keen interest in the survey and made available maps of their principal paddocks and detailed information as to management, value and place in the grazing scheme, grass introductions, and the relative merits of different species. These data are being analyzed and, together with the plant survey, will form a useful basis for classification of ranches as to type, and for mapping of plant associations as they are determined by ecological factors and ranch management. (Hosaka, Whitney.)

Station Grass Gardens

Many new species of pasture plants have been added to the station nursery at Pensacola Street (figure 1), which now contains 103 species or strains of grasses and 41 strains of legumes and miscellaneous plants. At the Haleakala Branch Station, 84 species of grasses are now growing. The station has facilities for adaptability trials of forage and pasture plants at the following locations:

	Altitude in Feet
Pensacola Street Station, Oahu	200
Poamoho Farm, Oahu	650
Haleakala Branch Station, Maui	2,180
Olinda Plots, Maui	3,700

It is particularly important in Hawaii that any studies of adaptation, growth habits, and persistence of pasture species be conducted over a considerable altitude range. Relative differences in vigor and persistence cause the plant associations to change markedly at different altitudes. Examples of this zonation in the successful introduction of new species in Hawaii are bromegrass (*Bromus unioloides*), Kentucky bluegrass (*Poa pratensis*), velvetgrass (*Holcus lanatus*), white clover (*Trifolium repens*), and the rye grasses (*Lolium spp.*), which grow well at altitudes above 2,500 feet; while pigeonpeas (*Cajanus cajan*), koa haole (*Leucaena glauca*), kiawe (*Prosopis chilensis*), and Para grass (*Panicum purpurascens*) are important pasture plants only at lower levels. (Wilsie, Whitney, Ripperton)

Figure 1.—A portion of the station's grass nursery at Pensacola Street, Honolulu, where 150 species of grasses and legumes are now growing, representing collections from many tropical and arid regions.

Cooperative Grass Gardens

As a part of the livestock feed project supported by sugar processing tax funds, grass gardens were established, in cooperation with the ranches, on the different islands as follow: 9 on Hawaii, 3 on Maui, 1 on Molokai, 3 on Oahu, and 2 on Kauai. Conditions on the

various tests vary greatly, with elevations ranging from sea level to 3,800 feet, and with annual rainfall from 5 to 100 inches. Forty species of grasses and 25 species of legumes and shrubs are under test. In 13 of the 18 gardens, the species were planted in rows and are being maintained, as nearly as possible, as pure species. In the other 5, mixtures were broadcast. Periodic visits are made to each of these tests and notes taken as to germination, stand, vigor, seeding, and persistence. Quadrat studies are being inaugurated in the mixtures to determine the trends in plant population over a period of years.

A number of recently introduced species not yet established on the ranges are showing great promise of future usefulness to Hawaiian ranches and dairies. The most important are as follow:

Cynodon. Giant Bermuda (*C. dactylon*) is growing strongly in both wet and very dry localities. Two new introductions from California (*C. barberi* and *C. plectostachyum*) are being watched with great interest.

Digitaria. D. milanjiana is especially promising in moderate to wet conditions. Another introduction received under the name of *D. pentzii* appears to be *D. milanjiana.* No viable seed has been collected but the grass is readily planted by cuttings. It offers special promise against such undesirable grasses as Hilo grass (*Paspalum conjugatum*) and yellow foxtail (*Setaria geniculata*).

Panicum. Switchgrass (*P. virgatum*) and coolah grass (*P. prolutum*) are upright, bunch grasses originating in the United States and in Australia, respectively. They appear well adapted at Pensacola Street and the growth seems exceptionally vigorous.

Andropogon. Australian bluegrass (*A. sericeus*) has grown well and seeded profusely in the very dry locations. Big bluestem (*A. furcatus*) and prairie beardgrass (*A. scoparius*), both from the arid western plains, look unusually promising at Pensacola Street nursery.

Bouteloua. These grama grasses, although slow to become established, are now growing well at Pensacola Street. Of the five species brought in, side-oats grama (*B. curtipendula*) and blue grama (*B. gracilis*) look most encouraging.

Tobosa grass (*Hilaria mutica*), from the arid mesas and deserts of western United States, and *Ischaemum laxum* and *Themeda australis,* both from Australia, are growing well in the nursery.

Of the previous introductions, molasses grass (*Melinis minutiflora*), Rhodes grass (*Chloris gayana*), and kikuyu (*Pennisetum clandestinium*) are showing great adaptability, thriving in wet as well as dry locations. (Ripperton, Burt, Whitney)

FODDER CROPS

Strains of Napier and Merker Grass

Eight seedling strains resulting from open pollination of Napier and crosses of Napier and Merker grasses are being compared, as to yield, with the standard Napier grass. The first year's results showed no significant difference between the standard Napier and the selected seedlings. The second year's results are as follow:

Table 1—Yields of green forage of eight strains of Merker and Napier grasses compared with that of the standard Napier—second year

Strain No.	Strain	Yield of green forage per acre
		Tons
34.10	Standard Napier	69.32
34.33	Open-pollinated Napier	94.86
34.18	Merker-Napier hybrid	87.97
34.30	Do	87.63
34.13	Napier-Merker hybrid	84.05
34.21	Do	94.53
34.23	Do	88.63
34.27	Do	85.33
34.37	Do	79.18

In the light of these encouraging results, the original row plantings of 38 strains, from which the 8 used in this trial were selected, are being studied. These plantings are now three years old and several strains not included in the present replicated trial appear worthy of further trial. (Wilsie, Takahashi, Akamine)

Frequency of Cutting of Napier Grass

In this experiment, begun in February 1935, the frequency of cutting of Napier grass is correlated with yield, persistence of stand, and nutrient content. Cuttings are made at intervals of 6, 8, 10, 12, and 14 weeks in the five respective treatments. Results at the end of

the first year showed increasing yields of forage with longer periods between cuttings. However, increases in the percentage of unpalatable portions more than offset the increases in total yield, so that the yield of palatable portions was greatest in the 6 weeks' treatment and smallest in the 14 weeks' treatment. The palatable portion was taken to be all leaves together with the stalk above the fifth visible ligule from the top. This separation was based on feeding trials with dairy cows.

By the end of the second year, the effect of cutting too frequently was plainly evident in low yield. The total palatable yield at the end of the 6 weeks' interval was far below that at the end of 8 weeks. In addition, examination of the stools in the various treatments showed a weakened condition with the 6 weeks' cutting period, the rootstalks being small, very numerous, and poorly rooted.

Results to date indicate that, under conditions existing at the university farm, eight to ten weeks constitute the most desirable interval between cuttings, this period being long enough to produce sturdy, long-lived stools with the highest total yield of palatable forage. (Ripperton, Takahashi, Akamine)

GERMINATION AND VIABILITY OF CROP SEEDS IN HAWAII

Tests started in the fall of 1935, to determine the best conditions for storage of crop seeds under humid tropical and subtropical conditions such as exist in Hawaii, were continued during the past year. In table 2 are recorded the results of the germination tests after 18 months of storage under various relative humidity conditions, at room temperatures averaging 75° F.

The above table shows very strikingly that control of humidity is a vital factor in seed storage at temperatures existing in Hawaii, which average about 75° F. The drop in percentage of germination when stored at 75 instead of 60 percent relative humidity is very sharp for most kinds of seed. The difference between species is quite evident. Soybeans do not germinate well at low relative humidities. Rice requires somewhat dryer air (about 45 percent humidity) for satisfactory storage. Corn and alfalfa were the most tolerant of the seeds tested. Lower percentages of germination in the air-tight control illustrate the need of air circulation in the storage of certain seeds.

Kind of seed	Variety	Initial germination	Germination under different conditions							
			Relative humidity						Air-tight control	Open control
			15	30	45	60	75	90		
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Soybean	Nanking	100	28	40	44	51	0	[1]	12	16
Garden bean	Kentucky Wonder	92	66	63	58	72	0	[1]	20	60
Corn	Guam	95	97	97	95	92	51	0	35	95
Alfalfa[2]	Hairy Peruvian	100	99	98	99	94	13	0	96	86
Lettuce[3]	Station Hybrid Ac. No. 1801	96	93	98	93	97	0	[1]	78	70
Rice	Taichee	91	87	97	96	41	0	[1]	[1]	0
Pennisetum ciliare[4]		44	44	25	50	39	[1]	[1]	21	14

[1] Seeds in this treatment dead in test of germination made three months previous.
[2] Seed coats cut on the sixth or seventh day of incubation to hasten germination.
[3] Germination in petri dish.
[4] Germination in soil can.

Table 2—Germination of seed at different relative humidities after 18 months of storage, at room temperature

The effect of temperature on seed storage is also being studied, each species being stored at 50°, 59°, and 68° F., with two relative humidities at each temperature, 30 and 60 percent. After 15 months of storage, all lots have retained their viability.

The results to date indicate that a relative humidity of 45 to 60 percent is best for storage at temperatures of 75° F., but if the temperature can be reduced to 60° F. or below, no humidity control is necessary. Of the various desiccating agents tested, calcium chloride was superior to concentrated sulphuric acid and calcium oxide for seed storage.

These tests are being continued to determine the interaction of time, humidity, and temperature. Both light- and dark-colored seed varieties of garden beans have been secured, and tests are being inaugurated to determine whether the statement often made that dark-colored seeds retain their viability longer than the light-colored variety is true.

Methods of accelerating the rate of germination of the hard-coated seed of koa haole (*Leucaena glauca*) have been studied. Without treatment, only 8 percent of the seeds germinated during a two months' period under standard conditions of temperature and humidity. Cutting the seed coat with a knife resulted in 100 percent germination. Immersion in water at 70° C. (158° F.) for 20 minutes gave a germination of 85 percent. Immersion in concentrated sulphuric acid (commercial grade) for 13 minutes gave a germination of 98 percent. The seeds treated with hot water or sulphuric acid have retained their viability after drying and storing for eleven months. Pretreatment of koa haole seed would seem to be a practical procedure since it induces quick germination and permits the plant to take advantage of the full growing season. (Akamine, Ripperton)

SWEETPOTATOES

Through the courtesy of Dr. V. R. Boswell of the U. S. Department of Agriculture, 31 varieties of sweetpotatoes were received in April and were added to the nursery at the Pensacola Street station. With these additions, there are now more than 100 known varieties in the nursery.

Five of the most promising seedlings were planted in the spring at Waipahu, Oahu, and Kohala, Hawaii, in order to study

the yield, quality, and shape of these seedlings under field conditions. Plots were laid out at random and each treatment was replicated six times. Yellow Yam and Nancy Hall were also included in the variety tests, as controls (figure 2).

It was found that growth of three-month-old seedlings in gallon cans was closely correlated with that of field-grown plants. Most of the seedlings which had no tubers when grown in gallon cans likewise produced few or no tubers when grown in the field. It was also found that examination of colors of both the skin and flesh of three-month-old seedlings gave a very accurate index of the colors of the mature field-grown tubers. Many seedlings can, therefore, be eliminated without actual field testing.

Figure 2.—Improving the shape, color, and quality of sweetpotatoes through breeding and selection. Left—Seedling 35.14; right—Nancy Hall. (Note the numerous ridgings on Nancy Hall as compared to the seedling; both were grown in heavy soil.)

Preliminary studies on the self- and cross-fertility or sterility of the sweetpotato were completed this spring. The findings are summarized as follow:

Flowers self-pollinated by isolation through the covering of the flowers with vegetable parchment bags invariably resulted in complete self-sterility. Even with self-hand pollination, self-sterility is very high in the sweetpotato. The use of bud pollinations and the use of end-fertility were entirely negative in overcoming self-

sterility. It was found that very little cross-pollination took place after 10 a.m. The degree of cross-fertility was quite variable, ranging from complete sterility to full fertility. Crosses involving freely flowering varieties were generally much more fertile than crosses between poorly flowering varieties. (Takahashi)

SWEET CORN

Since the introduction, in the fall of 1935, of U.S.D.A.-34 (figures 3 and 4), a tropical sweet corn from the Puerto Rico Experiment Station, three crops have been grown. In all three plantings the plants were vigorous and healthy, with growth habits similar to rank growing field corn. Under favorable conditions the plants grow from 8 to 12 feet tall. In the spring of 1937, U.S.D.A.-34, Guam, Golden Cross Bantam, and Oregon Evergreen were grown in four randomized blocks to test the resistance of these varieties to corn mosaic, which is the most serious disease of corn in Hawaii. Both U.S.D.A.-34 and Guam were found to be highly resistant to corn mosaic, with an infestation of approximately one percent. Golden Cross Bantam and Oregon Evergreen were highly susceptible to mosaic as shown in table 3. Other varieties of sweet corn received from the University of California at Davis were fairly susceptible to the mosaic. Although U.S.D.A.-34 makes the best growth in the summer, it also does remarkably well throughout the year. A majority of those who have tried this variety consider its quality about on a par with the best of the sweet corn varieties. It is believed that U.S.D.A.-34 holds excellent promise as a satisfactory sweet corn for the Territory because of its high quality and its ability to produce heavy crops consistently.

During the past year pure-line breeding was initiated on several varieties, including Guam and U.S.D.A.-34. We hope to speed up the work by growing three generations in a year. Breeding of new varieties by the backcross method has been continued. The following crosses and backcrosses have been made during the year: (1), Golden Cross Bantam-Guam hybrid backcrossed to Guam; (2), Narrow Grain Evergreen-Guam hybrid backcrossed to Guam; (3), U.S.D.A.-34 crossed with Guam; (4), Honey June crossed with Guam; and (5), Honey June crossed with U.S.D.A.-34.

Several first backcrosses were received from Davis Farm, California, during the past year. On the whole they have been satisfac-

Figure 3.—Typical ears of the sweet corn variety U.S.D.A.-34 at the prime harvesting stage.

Figure 4.—U.S.D.A.-34 and Golden Cross Bantam sweet corn growing at the Pensacola Street station, Honolulu. Left to right, first four rows—U.S.D.A.-34 (resistant to corn mosaic and corn earworm, vigorous in growth, the ears large, and the kernels sweet and of excellent quality); fifth row—Golden Cross Bantam, a standard mainland variety (susceptible to both corn mosaic and corn earworm, and not adapted to Hawaii).

tory and the work will be continued. However, U.S.D.A.-34 was substituted for both Honey June and Surcropper Sugar for backcrossing because of the resistance of U.S.D.A.-34 to corn mosaic and its robust growth habits. (Takahashi, Wilsie, Welch)

Table 3.—Relative resistance of sweet corn varieties to corn mosaic

Variety	Number of plants examined	Number of mosaic plants	Percent mosaic
Oregon Evergreen	95	38	40.0
Golden Cross Bantam	93	48	51.6
Guam (5 selections)	480	5	1.0
U.S.D.A.-34 (12 selections)	1,130	12	1.1
Honey June	46	8	17.4
Golden Bantam-Honey June backcross	48	12	25.0
Oregon Evergreen-Honey June backcross	48	13	27.1
Early Alameda-Surcropper Sugar backcross	49	14	28.6
Early Alameda-Honey June backcross	45	20	44.4
Golden Sunshine-Surcropper Sugar backcross	46	7	15.2
Golden Cross Bantam-Guam backcross	120	7	5.8

TARO INVESTIGATIONS

Taxonomic Classification

Taxonomic classification of all taro varieties available in Hawaii has been completed. Some 300 varietal names have been recorded for Hawaiian taros, many of which are synonyms. With the reduction of these varietal names to synonomy, there now exist in Hawaii approximately 85 distinct varieties. Although the distinguishing characteristics, in many cases, are slight, they are distinct and constant. The following are some of the more important characteristics. (Whitney)

A. Kalo producing rhizomes

AA. Kalo not producing rhizomes

B. Leaf blades cut to the petioles; petioles with a conspicuous ridge on inner surface

C. Corm flesh pink or pinkish-lilac

CC. Corm flesh white

BB. Leaf blades not cut to the petioles; petioles without a conspicuous ridge on inner surface

C. Corms branching at top

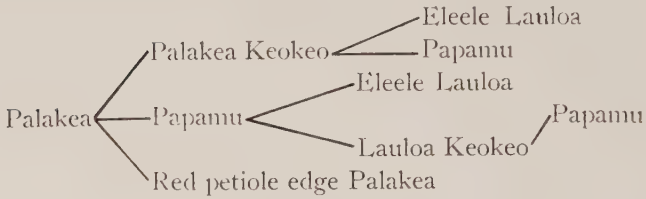
CC. Corms not branching at top
D. Leaf blades distinctly mottled
DD. Leaf blades not distinctly mottled
E. Petioles striped
EE. Petioles not striped
F. Petioles extremely long; leaf blades long and narrow
FF. Petioles extremely short, stocky; leaf blades broadly ovate, rather crinkly
G. Leaf blades distinctly cupped
GG. Leaf blades not cupped

Seed Production and Vegetative Mutation

Taro has been propagated through the centuries by the asexual method, and seed production has been considered rare and of little significance. In December 1936, a plant of the variety Mana Opelu was found with greatly enlarged ovaries. Some 200 seeds were secured and planted, eight of which survived. During May and June of 1937 there was a period of unusually profuse blossoming in the wetland taro fields of windward Oahu as well as in the station nursery at Pensacola Street. In the former fields, several thousand naturally developed seeds of the varieties Piko Kea and Piko Uliuli were collected; these are now growing in the station nursery. At the station, no natural crossing occurred but many hand pollinations were successful.

The following varieties were successfully self-pollinated: Ulaula Kumu, Piko Kea, Piko Uliuli, Makaopio, Mana Opelu, Tore Tore, Ohe, and Tahitian; the successful crosses were: Ohe × Eleele Makoko, Ulaula Kumu × Makaopio, and Kai Kea × Kalalau. The last named cross is particularly interesting in view of the fact that about fifty self-pollinations of Kai Kea were unsuccessful. Seedlings of nearly all of these hand-pollinated seeds are now growing vigorously. Apparently the taro plant does not develop seed unless the flower is pollinated during vigorous vegetative growth.

A considerable amount of vegetative mutation was found in the group Lauloa, growing at Pensacola Street. The following diagram shows the outstanding mutants:



These mutants have previously existed in the Territory as established varieties.

This tendency to vegetative mutation, together with the occasional development of seed, furnishes an explanation of the great number of taro varieties which have resulted, apparently without any systematic attempt to develop them other than to plant new varieties as they appeared. These findings open up an entirely new field in the selection and breeding of taro. It seems quite probable that selection of mutations and hybrids may be an effective means of developing disease-resistant varieties, as well as varieties with special adaptability to the production of dried products. (Whitney, Kikuta)

Field Experiments with Upland Taro

Fertilizer, spacing, and varietal tests with upland taro on Oahu, Maui, and Hawaii were harvested; the yields were low in nearly all instances. Cultural notes point to a number of important causes of low yields, particularly in new areas which had been lying fallow. Weed control and proper cultivation are of paramount importance in producing good yields. The field should be kept clean of weeds during the period of vigorous vegetative growth; during the subsequent period of gradual diminution of top growth and storage of starch in the rootstock no cultivation or clearing of the weeds is advisable. The roots of the taro are close to the surface and any cutting or disturbing of the root system causes a rapid decline in growth as well as the development of rot. In a field containing many dormant weed seeds, the development of weeds is so rapid that the maturing taro plant is often choked out.

Yields of upland or nonirrigated taro, based on small plot harvests, have varied from 1 to 12 tons per acre for the Hawaiian taros. The Japanese and Chinese varieties have yielded from 12 to 19 tons per acre. These latter offer possibilities for dried products

which warrant further investigation. Preliminary factory tests indicate, however, that such dried products do not have qualities identical with those of the Hawaiian varieties.

Fertilizer experiments with upland taro at both Wahiawa, Oahu, and Kaupakalua, Maui, indicated that applications of ammonium sulphate resulted in decreased yields. In both experiments, however, poor cultural conditions prevailed, so this conclusion may not apply to normal conditions.

In view of the need of other crops in the coffee-growing section of Kona, investigations of taro culture have been instituted. The crop is known to produce exceptionally well in the middle and upper rainfall belts. It is a common belief that taro cannot be grown continuously in the same field, and in the chief taro-growing section in Kona new areas are constantly being cleared of guava, at considerable expense, for growth of taro. In cooperation with the Agricultural Extension Service, fertilizer experiments have been installed in newly cleared and old fields in this section. At the Kona Branch Station, both fertilizer and variety trials have been started, interplanted among young coffee trees. (Ripperton, Bowers)

HORTICULTURE

Horticultural investigations have developed along a number of definite lines, the final objective in all investigations being to improve the crop by breeding and selection, to improve yield and quality through cultural treatments, and to gain an understanding of the effects of seasons, climate, and soil on growth and reproduction of the principal crops.

CYTOLOGICAL AND ANATOMICAL INVESTIGATIONS

Papaya

The occurrence of male and female plants in approximately equal numbers in progenies of certain dioecious strains of papaya suggests some sex-determining mechanism. However, the segregations in hermaphrodite strains rather indicate a Mendelian or factorial basis for sex determination. Preliminary cytological investigations of dioecious and hermaphrodite individuals of *Carica papaya,* as well as of individuals of *C. cauliflora* and *C. quercifolia,* show that a 2N number of 18 chromosomes exists in every case,

regardless of the sex of the plant. *Carica peltata* and *C. candamarcensis* are also being investigated. The results do not indicate a dimorphic chromosome mechanism of sex determination and agree with the observations of Lindsay.[1] In the hermaphrodite forms, the occurrence of two or more flower types on the same inflorescence and the seasonal shift in the proportion of flowers of different types on individual trees lend support to the arguments of Yampolsky.[2] However, the general sex type of individual trees of papaya is relatively constant, even though influenced by nutritional and environmental factors, and is doubtless determined by definitely localized quantitative or qualitative factors. Progenies arising from controlled pollinations between different sex forms are now being grown and will add further evidence to that already gained from studies of open-pollinated progenies. (Beaumont, Storey)

PASSIFLORA

The genus *Passiflora* comprises approximately 350 species of tropical and subtropical vines, mostly of Central and South American origin. Twenty-two species are found in Hawaii growing both under cultivation and in a naturalized wild state. Gaiser (1930) records the work of Heitz who determined the chromosome numbers of *P. caerulea* as 2N = 18, and of *P. princeps-coccinea* as N = 9 and 2N = 18. Nakajima also gives the chromosome number of *P. caerulea* as 2N = 18. Of the 22 species in Hawaii, the chromosome counts of 17 were found to be as follow:

2N = 12—*P. pulchella.*

2N = 18—*P. edulis; P. edulis f. flavicarpa; P. incarnata; P. laurifloria; P. ligularis; P. maliformis; P. maliformis* × *laurifolia; P. mollissima; P. pfordtii; P. quadrangularis; P. seemanni; P. subpeltata; P. vitifolia.*

2N = 20—*P. foetida; P. foetida* var. *gossypifolia.*

2N = 24—*P. suberosa.*

2N = 36—*P. suberosa.*

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[1] American Journal of Botany, Vol. 17, No. 2, p. 169.

[2] American Journal of Botany, Vol. 7, No. 3, p. 99.

The somatic numbers make up a heteroploid series with an assumed basic number of N = 6. Multivalent configurations in meiosis in the 2N = 18 group, as well as morphological similarities in somatic chromosomes in some of the species, suggest that these species had a polyploid origin. The closeness of relationship is indicated by the fair degree of compatibility among them which has led to the production of interspecific hybrids. The results of these investigations are in manuscript form for publication. (Storey)

MACADAMIA

Structure of Fruit. The macadamia nut, in a botanical sense, is not a nut but a seed, and the fruit is not a drupe, as it has generally been described (F. von Mueller, Engler and Prantl, Bailey, Bentham and Hooker), but a follicle. The dry, leathery pericarp is made up of two tissues, the exocarp and the endocarp, and is dehiscent along a single suture. The hard, thick shell that encloses the kernel is clearly differentiated into testa and tegmen which have developed from the integuments of the ovule.

The results of this study are in manuscript form for publication. They confirm the conclusions drawn by W. D. Francis,[1] whose report was found after the present study was near completion. (Storey, Hartung)

Anatomy of Buds. In conjunction with consideration of factors influencing flowering and fruit set of the macadamia, a study of the dormant buds was undertaken. There are three buds in the axil of each leaf and three or four leaves at each node, making a possible total of twelve dormant buds. The three buds in each leaf axis are arranged one above the other, the uppermost generally being the largest. The dormant buds seem to be purely meristematic as no differentiation of flower parts or of true leaves is apparent. Food storage or other physiological conditions in the tree or branch at the time active growth of a bud is initiated appear to determine whether a vegetative shoot or an inflorescence will develop. The various conditions determining the course of development are a phase of another project. The studies on the development of the inflorescence and floral parts are practically complete. (Storey, Hartung)

[1] Proc. Roy. Soc. Queensland, XXXIX, No. 4, 1927.

GENETICS, BREEDING, AND SELECTION

Papaya

Papaya breeding investigations as developed during the year may be divided into three phases: (1) The growing of numerous types and strains, foreign and local, for the purpose of obtaining an inventory of the fruit and plant characters in *Carica papaya* and closely related species of the genus; (2) controlled breeding to secure a genetic analysis of inheritance, and for combinations of desirable fruit and plant characters into new strains or varieties by crossing and subsequent inbreeding or backcrossing; and (3) controlled pollination of the most desirable types of different strains for the purpose of securing quantities of improved seed stock for distribution.

Four plantings have been made, the last not as yet complete, totaling 47 accessions and 9,536 plants. These plantings are at Kailua and Waialua. Some of the striking differences in plant characters among the strains, and often among individuals of the same strains were: Resistance or susceptibility to mildew; dwarf, semi-dwarf or tall stature; no lateral branches, few, or many; acute or obtuse angle of the leaf petiole relative to the stem axis; early flowering and fruiting; length of peduncle; color of stem and flower; and dioecious, monoecious, or hermaphrodite progenies.

Differences in fruit characters were: Thickness and regularity of flesh; size and shape of fruit, color of flesh, quantity of seeds; fibrous and fleshy funiculi or light and inconspicuous funiculi; shape of cavity; texture of flesh; quality; and susceptibility to a soft rot (*Rhizopus*).

These and other plant and fruit characters provide excellent material for breeding and development of strains. In addition, the plants are being used for disease control, thinning, and physiological studies.

The inheritance of sex is of primary consideration in determining a breeding program. The twenty-three progenies being planted at Waialua are the first progenies from controlled pollinations. These crosses were made in order to further studies on the segregation of the different sex types, and on thickness of flesh, size, and shape of fruit. A definite breeding plan for further studies on sex inheritance is being followed.

Superior individuals of the most desirable types are being selected and seed saved for distribution until definite varieties can be developed. (Beaumont, Storey)

MACADAMIA

Material progress has been made in the selection of superior types of macadamia (figure 5), their propagation, testing, and description as varieties. During the past crop season, approximately 15,000 bearing trees were surveyed. Descriptions of 320 of the most promising trees and analyses of nut samples were completed. From the 320 trees, 46 were selected for propagation, testing, and final selection. Most of these have been propagated in sufficient numbers to carry out the plan of setting out five replicated tests at different locations to secure an accurate and quick reading on the adaptability, growth and yield responses, quality, etc., of the different varieties. Those performing best will be named and introduced as horticultural varieties.

Selection work necessitated investigations on nursery propagation and top-working. By employing the principle discovered in relation to litchi propagation, of high carbohydrate storage in the stock and scion, a high degree of success in grafting was experienced. During the past season the majority of the stocks were less than one year of age and had not accumulated sufficient reserves, so that the percentage of successful grafts was lower than in the previous season. However, the results were fair considering the condition and size of the stocks, the necessity of using scions shipped through the mails, and the time of year when the seedlings were grafted.

The selection work also emphasized the desirability of top-working a percentage of the trees in bearing groves. Three top-working experiments were established to compare different methods and treatments. Ordinary methods, i.e., cleft, bark, and inlay-grafting of dehorned trees, produced such poor results as to be termed unsuccessful, only occasional scions forming a successful graft union. By grafting suckers arising from the stubs and trunk, high percentages of successful grafts were obtained (figure 6). These results are in manuscript for publication as an experiment station circular. (Moltzau)

Figure 5.—Macadamia nursery—four-month-old stock.

TOMATO

The soil and climatic conditions of the Territory are distinctly different from those existing on the mainland, yet the varieties of truck crops grown are largely obtained from mainland seedsmen. No concerted effort has been made, heretofore, to develop varieties adapted to Hawaiian conditions, although standard mainland varieties apparently are poorly adapted. The cooperation was sought of investigators conducting breeding investigations under somewhat comparable conditions (W. S. Porte, U. S. Department of Agriculture; and J. C. Miller, Louisiana Experiment Station). Inbred lines and strains produced under conditions in Florida and Louisiana have been much superior to standard varieties. Further selection within these lines is being carried on, and later hybridization among the most promising strains and varieties will be practiced.

Hybridization of the Hawaiian cherry and plum tomatoes with standard varieties has been discontinued. The Hawaiian types seem more susceptible to mosaic and blight, and the possibility of

securing an amphidiploid of commercial value is remote. It is hoped that resistance to melon fly and disease will be found in varieties of hybrids of the large fruited types. (Welch, Takahashi)

Figure 6.—Fourteen-year-old rough-shell tree (*Macadamia ternifolia*), top-worked to selected smooth-shell variety, showing successful side grafts on sucker growth. The suckers will be cut back to the point of graft union when the grafts become well established.

LETTUCE

Lettuce-breeding investigations resulted in the development of some lines of considerable promise. The plants made good growth, but, in general, heading was poorer than in previous years due to climatic conditions. Progenies of Mignonette crossed with 1801 hybrid showed the least bolting and the highest percentage of large solid heads. Strains furnished by R. C. Thompson (U. S. Department of Agriculture) made vigorous growth and were of fine appearance; many of the heads were fairly large but were too loose to meet market requirements. Cosberg showed the best heading qualities at Honolulu although the heads were small. A large number of selections were made and seed saved. Some of these strains

are being grown at the present time at Waimea (elevation 2,700 feet) for further test, observation, and selection. All of this breeding material together with the lettuce variety accessions will be tried at Waimea, which is perhaps the most important lettuce-producing area in the Territory, in the hope of developing New York types that will head well throughout the year. (Welch, Takahashi)

White Potato

No active potato hybridization and breeding is in progress or immediately contemplated. However, through cooperation with F. J. Stevenson (U. S. Department of Agriculture), Julian C. Miller, and other potato breeders, various new selections and progenies are being obtained for test and further selection. Emphasis is being placed on blight, mosaic, and scab resistance, yield, color, and quality. Approximately 50 selections are being held in cold storage for planting in November or December. (Beaumont, Welch)

PHYSIOLOGICAL INVESTIGATIONS

It seems clear that growth, flower bud formation, fruit setting, and fruit development are intimately related to and governed largely by nitrogen and carbohydrate metabolism. In Hawaii the rainfall, which affects soil fertility and soil nitrogen, and light, which affects carbohydrate synthesis, vary tremendously in different localities. With the uniformly favorable growth temperatures existing throughout the year, the problem of developing a carbohydrate-nitrogen relationship in the plant favorable to flower differentiation, and at the most desirable season of the year, becomes of extreme importance. The macadamia, mango, litchi, lungan, and other tropical plants do not enter a rest period but may make a flush of vegetative growth at any season, depending on the nitrogen and water supply, thus utilizing any accumulated carbohydrate reserves. Their blossoming is often sporadic and uncertain. A series of investigations has been initiated to determine whether the nitrogen-carbohydrate balance may be affected by culture, fertilizer, pruning, or irrigation. (Jones)

MACADAMIA

Perhaps one of the best indices of the cultural and nutritional requirements of a tree in maturing a crop of fruit is an understanding of the chemical and growth changes occurring from time of setting until the fruit drops. Such a series of analyses has been undertaken, but will not be complete until the present crop matures. Blossoming clusters were tagged and, as soon as the developing fruits were large enough to fractionate into pericarp, seed coats, and embryo, and at subsequent intervals thereafter, samples were preserved for chemical analysis. (Jones)

COFFEE

An investigation was begun on the growth and fruiting responses of the coffee tree as influenced by different degrees and systems of renewal pruning. Regularity of annual bearing; seasonal uniformity of blossoming; size, grade, and quality of fruit; elevation of fruiting surface above the ground; ease of picking; and economy in labor and fertilizers are some of the factors being considered. Further studies on pruning and the development of type trees were undertaken, using trees from an earlier pruning experiment and trees available at the Kona Branch Station. Light, rainfall, and temperature records are also being obtained. (Beaumont)

TOMATO

The tomato is one of the most delicately balanced plants as regards growth and fruiting behavior in relation to light, nutrients, and water. Detailed physiological investigations of this plant were begun with the idea that the findings would apply not only to more successful culture of the tomato crop but also, in part, to the culture of other crops.

The analyses of the first planting are near enough to completion to show the trends in the chemical composition of the plants. The fertilizer treatments were: None, 300 pounds, 600 pounds, and 1,200 pounds nitrogen per acre; none, 500 pounds, 1,000 pounds and 2,000 pounds phosphorus per acre; and 600 pounds potassium per acre. There was very little difference in yield of fruit under the different fertilizer treatments. This lack of response by the plants was due to the high state of fertility prior to treatment.

From the chemical analyses and the yield records it was apparent that the nutrient elements, nitrogen and phosphorus, are not limiting factors in tomato production at Waipahu. Other factors such as water and light are or could easily become limiting at the Waipahu site. (Jones)

Plant Propagation

Asexual propagation of the litchi and macadamia has been considered extremely difficult. Heretofore, only a few successful grafts of each have been recorded. Propagation of the litchi has been almost entirely limited to air layering or inarching. Investigations were undertaken to devise easier and more rapid methods of propagation (figure 7). Saturated acetylene water and several plant hormones with and without bottom heat and in the sweat box were tried with little or no effect on the rooting of litchi cuttings and the percentage of successful grafts. Microchemical and anatomical examinations of the cuttings and scions failed to reveal any stored reserves. It was deduced, therefore, that the lack of response was due to the absence of the reserves necessary for production of new tissues, not only in rooting but also in forming a graft union. By ringing the litchi branch three weeks before it was to be used as a scion, and forcing a high accumulation of starches, the percentage of successful grafts was immediately raised from + to 80 percent. Similar results were obtained with macadamia. The significant results of these investigations are in manuscript for publication as a station circular entitled "Nursery Propagation and Top-working of the Macadamia," and as an announcement in *Science*. The results seem to be of considerable significance and of wide application, particularly under uniform annual temperature and rainfall conditions where seasonal changes giving rise to accumulation of reserves do not occur. (Jones, Storey)

Storage

Papaya. The possibilities for export of the papaya may prove very promising. That cold treatment of the fruit for 12 days at 32° to 34° F. will kill fruit fly and melon fly larvae and pupae has been shown by workers of the Bureau of Entomology and Plant Quarantine, Honolulu. A number of preliminary tests have been run

to observe the effects of various storage temperatures on fruit of different stages of maturity, and on condition and quality after removal from storage. When picked full-grown but green and held

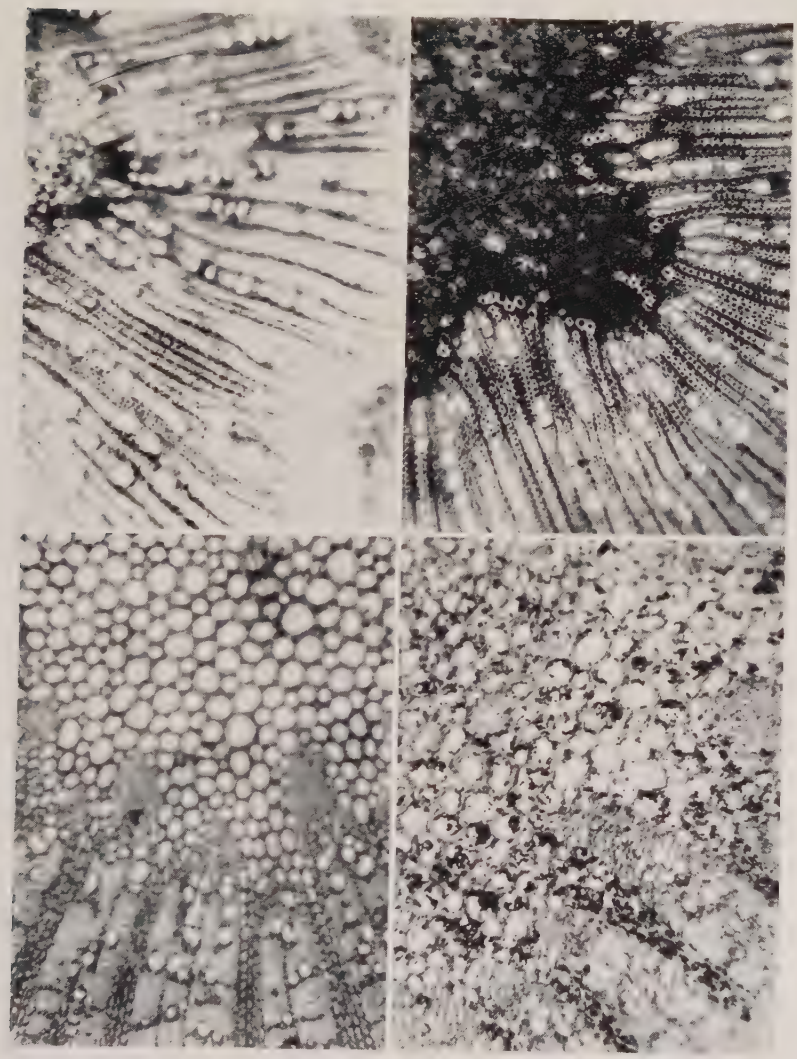


Figure 7.—Girdling of tree stems results in starch accumulation and successful grafting when these stems are used as scions. Dark areas of transverse stem section show starch (stained with IKI solution). Upper left –litchi not girdled; upper right —litchi girdled; lower left—macadamia not girdled; lower right –macadamia girdled.

for 12 days, the fruit failed to ripen when subsequently removed from cold storage to room temperature. There was only a slight development of color in the flesh and none in the skin, no flavor developed, a high rate of water loss occurred, and the fruit decayed before ripening. When picked firm ripe, with practically full color development of the flesh but only slight color of the skin, the fruit was preserved in its original condition in storage at 32° to 34° F. When in good condition, such fruit may be held for an additional 6 or 7 days at 50° F., but at room temperature ripening, breakdown, and decay proceed rapidly.

Two storage diseases are serious. These, according to G. K. Parris, are caused by species of *Colletotrichum* and of *Rhizopus*.

Based on these trials, a more detailed investigation of the changes occurring in the fruit during and after storage at various controlled temperatures has been initiated. (Jones)

Potato. The source of seed potatoes for the winter crop is a problem of great economic importance in the Territory. The possibility of holding over seed from one crop to the next is worthy of consideration for many economic reasons. Potatoes are harvested over a period of four or more months, and there is considerable latitude in the date of harvest, air temperature at time of digging, size of tuber, and market value, as well as other factors affecting the economy of the practice. The spread of mosaic diseases does not now appear to be a serious factor in the winter crop. The storage temperature is of great importance, and a storage test is now in progress using four temperatures—outside covered shed temperature, 50°, 40°, and 32° F. cold storage. (Welch, Jones)

Cultural Experiments

Definite plans have been made to establish cultural experiments with the principal fruits such as litchi, mango, citrus, and avocado. All of the plants must be propagated because no local supply is available. Most of the propagations have been made and the plants should be ready for transplanting to the field in one year.

Field cultural experiments with truck crops have been held in abeyance until the better varieties could be established. (See Vegetable Variety Tests.) (Beaumont)

VARIETY TESTING

Citrus Fruits

A number of new varieties of citrus fruits of local origin have been added to the variety collections of the station. These are being propagated for test. In addition, a number of accessions from outside sources have been received. The following are already on hand in large tubs and are ready for planting: Minneola tangelo, Orlando tangelo, Perrine lemon, Lakeland lime, Nippon kumquat, Seminole tangelo, Sunshine grapefruit, Italian citron, Corsican citron, Eureka lemon, and Villa Franca lemon. For later planting, the following varieties of grafted trees are in nursery rows at the north end of field C-IV: Bowen grapefruit, Thompson grapefruit, Davis grapefruit, Mott grapefruit, Foster grapefruit, seedless lemon from Kona, Tahiti lime, Thompson Navel orange, Washington Navel orange, Kona orange, and West Indian lime.

The Tahiti orange (H.A.E.S. Hort. Acc. No. 5701), received in 1933 from the late G. P. Wilder, is producing a small crop of fruit this season. In Tahiti, where Wilder reported this variety as growing strongly in the mountains, the parent tree is seedless and the fruit is considered to be of superior quality. Under the conditions obtaining at the Pensacola Street station, the tree grows slowly and resembles very closely the so-called "Kona" orange. Growing among a mixed collection of citrus in the orchard, every fruit to date has been found to contain seeds, the number varying from 1 to about 10 in a fruit. The only other known tree of this variety in the vicinity of Honolulu grows upon the Wilder estate, but up to the present it has not borne fruit.

The propagation of the principal commercial varieties of orange, grapefruit, lemon, and lime on three different rootstocks is progressing as rapidly as scions and stocks become available. Preliminary arrangements for setting out one or two collections of varieties and stocks have been made. (Beaumont)

Vegetables

Fifty-three varieties of vegetable seeds were received during the quarter ending June 30, 1937, bringing the total to 415 vegetable accessions for the year. One hundred thirteen field experiments have been planted on three islands—49 at Waipahu, Oahu; 41 at

Kamuela, Hawaii; and 23 at Haleakala Branch Station, Makawao, Maui.

Waipahu Project. Table 4 summarizes yields of the high ranking varieties and strains of tomatoes grown at Waipahu during the fall of 1936. There were about 1,800 plants per acre, with rows 6 feet apart and plants spaced 4 feet apart in the rows. Planting occurred August 14 to 18 and harvesting was terminated December 22.

A number of additional variety trials with vegetables have been conducted at Waipahu during the year. In many cases the final results are not yet tabulated nor have definite selections been made. A partial list follows: Eggplant, peppers, bush and pole beans, cabbage, carrots, beets, chard, turnips, rutabagas, broccoli, and onions.

Outstanding varieties in the earlier trials have been: *Cabbage*—Copenhagen Market, Resistant Detroit, Golden Acre, Marion Market, and Louisiana Copenhagen; *Carrots*—Chanteney strains, Danvers Half Long, Imperator and Morse's Bunching; *Beets*—Good for All, Early Wonder, Detroit Dark Red, and Crimson Globe; *Chard*—Fordhook Giant.

Waimea Trials. The varietal trials at the Kato Farm have not, in the main, proven as satisfactory as had been anticipated. Nevertheless, more is known now regarding the kinds of vegetables that should be grown under the wet, cool conditions existing in the Waimea district, the seasons best adapted to these vegetables, and the best varieties. Other problems relating to cultural practices and disease are more familiar to the investigators so that these items may also be incorporated in future experiments in the hope that the Waimea farmers will be able to compete better with importations of certain mainland vegetables.

Haleakala Trials. At the Haleakala Branch Station, 19 field experiments dealing with truck crops were planted in the fall of 1936. Eight of these had to be discarded because of poor germination or stand, caused in part by the rainy, inclement weather. The remaining experiments were harvested during the spring of 1937 but the results of these experiments have not yet been summarized. Additional field experiments were planted in June of 1937.

Yield order	Accession No.	Variety or strain	Yield per acre				
			No. 1	No. 2	Culls	Total	Total No. 1 and No. 2
			Pounds	Pounds	Pounds	Pounds	Pounds
1	15	Florida hybrid	9,057	12,269	15,173	36,499	21,326
2	9	Do	4,610	15,718	14,393	34,721	20,328
3	14	Do	4,555	15,010	14,756	34,321	19,565
4	19	Do	3,939	15,355	15,173	34,467	19,294
5	4	Do	3,830	14,574	12,378	30,782	18,404
6	1	Do	3,467	14,847	14,030	32,344	18,314
7	32	Florida Pritchard	4,864	13,358	15,065	33,287	18,222
8	18	Florida hybrid	5,136	12,814	15,518	33,468	17,950
9	24	Do	2,468	15,446	12,505	30,419	17,914
10	11	Do	6,189	11,543	13,903	31,635	17,732
11	38	Louisiana hybrid	4,719	12,868	17,478	35,065	17,587
12	3	Florida hybrid	4,047	13,286	12,596	29,929	17,333
13	37	Louisiana hybrid	3,684	13,395	15,119	32,198	17,079
14	13	Florida hybrid	3,703	13,159	11,598	28,460	16,862
15	8	Do	5,881	10,635	10,545	27,062	16,517

Table 4.—Tomato strain and variety yields

The Haleakala Branch Station is several miles outside of the truck crop belt on Maui and the site does not seem particularly suited to some kinds of vegetables. For this reason, the superintendent of the branch station will, in the future, probably conduct some of the truck crop experiments in cooperation with growers in the truck crop areas rather than at the branch station. (Welch, Thompson)

PLANT INTRODUCTIONS

The following accessions were received during the year as seeds, scions, or plants. Vegetables are not included. (Beaumont)

Kind of plant	*Number of varieties*	*Source*	*Type of material*
Litchi chinensis	4	Lingnan University	Rooted plants
Do	4	Do	Scions
Do	2	D. T. Fleming	Do
Citrus—tangelo	4	H. P. Traub, Orlando, Fla.	Do
lemon	1	Do	Do
lime	1	Do	Do
grapefruit	6	Do	Do
kumquat	1	Do	Do
pomelo	9	Do	Do
Carica papaya	6	Durban, Africa	Seed
Do	2	Canal Zone	Do
Do	1	Australia	Do
Do	7	Havana, Cuba	Do
Do	2	Philippine Islands	Do
Do	4	Caroline Islands (Kusaie)	Do
Do	1	S.P.I. 123,615	Do
Carica cauliflora		Canal Zone	Do
Attalea speciosa (Babassu palm)		S.P.I. Washington, D.C.	Do
Mangifera indica	1	Brisbane, Australia	Scions
Averrhoa bilimbi		Philippine Islands	Seed
Garcinia mangostana		Puerto Rico	Seedlings
Do		Philippine Islands	Seed
Aleurites cordata		S.P.I. Washington, D.C.	Seed
Aleurites trisperma		Do	Do
Eugenia sp.		Saharanpur, India	Do
Macadamia sp.		S.P.I. Washington, D.C.	Seedlings
Do	3	Brisbane, Australia	Scions
Lansium domesticum		Philippine Islands	Seed
Do		B.P.I. Manila, P.I.	Do
Myrciaria cauliflora (Jaboticaba)		Tela, Honduras	Do
Annona squamosa (custard apple)		Brisbane, Australia	Plants

PLANT PATHOLOGY

DISEASES OF THE TARO

Research work on diseases of the taro plant (*Colocasia esculenta*) has been continued during the past year. Laboratory experiments, together with pot and field tests, have constituted the program of work. The Islands of Molokai, Kauai, and Hawaii have been visited in connection with field surveys on the diseases of taro.

Soft Rot of the Taro Corm

Continued isolation studies have shown *Pythium* sp. to be the outstanding etiological agent of the soft rot of the taro corm. This fungus is quite distinct from *Pythium gramicolum* Subramaniam, the causal agent of root rot of sugarcane in Hawaii and elsewhere. No attempt has been made during the past year to identify the species of *Pythium* causing soft rot of taro.

Evidence in support of drying and plowing taro soil between crops, previously reported as a practical method of controlling soft rot, has continued to accumulate. Several growers on Oahu and elsewhere are finding this method effective, with consequent reduction in losses from disease.

Pot tests installed during the period December 1935 to March 1936 have been harvested during the past year, as have field tests in two different localities on Oahu. The percentages of infection with *Pythium* sp. obtained with taro plants grown under submerged conditions in various soils have been: 5 percent in sterilized soil; 21 percent in nonsterilized soil from a diseased patch; and 57 percent in sterilized soil later infested with *Pythium* sp. The fungus was isolated and identified in every case. Infection obtained in sterilized soil is believed to have originated from inoculum carried on the surface of the nondisinfested planting material.

Laboratory tests have shown that *Pythium* sp. does not grow readily below pH 5.0. To test the effect of acidified water on the growth of the taro plant and its possible value in disease control, a preliminary pot test with taro plants in infested soil was conducted. Plants receiving water of pH 4 and pH 5 grew just as well as, if not better than, plants receiving water of other pH values, showed no soft rot, and gave a 30 percent higher yield than plants at other pH values. Plants grown at pH 2, 3, 6 and 7.2 showed 40, 40, 20, and 10 percent rot respectively.

Observations have shown that taro planted in soils which have been permitted to dry out and become aerated have less soft rot than in soils kept continuously submerged. A pot test using fresh soil from a diseased area was set up with the following soil treatments: (1) Soil thoroughly dried in the sun for three weeks; (2) soil partially sun-dried; and (3) soil from the field in natural condition. Taro was grown in these pots under submerged conditions and at harvest only the lot grown in soil direct from the field was diseased. Fifty percent of the plants were diseased and *Pythium* sp. was isolated from each plant.

Field experiments in the control of soft rot of the taro corm were harvested at two localities on Oahu (Punaluu and Heeia).

Using two standard wet-land taro varieties, Haehae and Piialii, the following chemicals applied to the soil prior to planting have given significant reductions in rot: Copper sulphate (300 and 600 pounds per acre), lime (2 and 4 tons per acre), borax (50 pounds per acre), acetic acid (50 cubic centimeters of 4-percent and 11-percent solution per square foot), mercuric chloride (10 and 20 pounds per acre), formalin (8-percent solution, 1 pint per square foot), chloropicrin (150 and 300 pounds per acre), tetrachlorethane (600 and 1,200 pounds per acre), and semesan huli dip (10 and 20 minutes in solution of 1 ounce semesan in 3 gallons of water). Sulphur (500 and 1,000 pounds per acre) applied to the soil for acidification purposes increased the incidence of rot.

In the present tests, Piialii was more susceptible to soft rot than Haehae. The percentages of difference varied from 4 to 17.

Chloropicrin and tetrachlorethane produced foliar stimulation of the taro plant and also a high percentage of corms of a low starch content ("loliloli taro"). Loliloli taro is of no value in the manufacture of poi or taro flour.

Taro plants grown in coral sand watered with a complete nutrient solution throughout their life cycle have shown a higher percentage of loliloli corms than plants which received minus nitrogen nutrient solution during the last five months of their growth. It is believed that nitrogen released from the soil or soil organisms as a result of chloropicrin and tetrachlorethane applications stimulated the taro plants. Energy necessary to maintain vigorous foliar development was obtained from the corm with consequent loss of starch.

Field tests to determine the role of nitrogen in the production of loliloli taro and also the susceptibility of the taro plant to soft rot have been installed. (Parris)

VASCULAR NECROSIS OF THE TARO CORM

The etiology of this disease is still unknown. From a small percentage of over 200 isolations a phycomycete has been isolated on potato dextrose agar. The fungus is characterized by a slow, submerged growth. It is short-lived on the artificial media tried. Inoculations with this organism produce a reddening and hardening of the vascular tissue of the corm, symptoms somewhat similar to those found in naturally infected corms. In a single instance, hyphae of this fungus have been seen within the vascular system of microtome sections of diseased taro.

Lesions are easily traced from internal necrosis outward to dead or dying roots on the exterior of the taro corm.

One hundred percent infection has been obtained when hulis from diseased corms were planted in sterilized soil under submerged conditions. A preplanting huli dip in 1:1:3 bordeaux paste was of no value in controlling transmission of the disease. Hulis from healthy corms planted in submerged soil from a diseased patch and also in sterilized soil infested with diseased corm material developed 11 and 50 percent disease respectively. No diseased plants were obtained when hulis were given a preplanting dip in bordeaux paste.

The susceptibility of 32 taro varieties to vascular necrosis was tested by planting hulis in soil from a diseased taro patch. Five varieties, namely, Weo No. 2202, Haokea No. 2920, Uahiapele No. 2207, Lehuaapei No. 2109, and Makaopio No. 2204, showed no disease. The varieties Piko Kea No. 2100, Kai Uliuli, and Miyako No. 1882 were slightly susceptible. The remaining 24 varieties showed the disease in more or less severe form. The commercial variety Haehae is more susceptible than Piialii.

Additional data on varietal resistance will be obtained from field tests installed in three localities on Oahu.

The root-knot nematode (*Heterodera marioni*) has been found on the roots of upland taro plants grown on old pineapple fields. This nematode has never been encountered on submerged taro. (Parris)

Pathogens of the Taro Leaf

Inoculations with *Phytophthora colocasiae* and *Phyllosticta colocasiophila* on 45 varieties of taro have shown that none of the varieties tested is resistant to *P. colocasiae*. The variety Manini Uliuli is resistant to *P. colocasiophila*. Resistance is lost if the epidermis of this variety is torn or broken. *Xanthosoma macrophilla*, the West Indian eddoe, is resistant to *P. colocasiae*. *P. colocasiophila* will produce infection if introduced through a broken epidermis.

Macrosporium sp. has not been observed on the varieties Apii, Apu, or Lauloa Launui but has been seen on 40 other taro varieties.

P. colocasiae can be controlled by applications of 4-4-50 bordeaux at 10-day intervals. Sprayed plants are taller and produce more ohas per plant than unsprayed plants. Preliminary data indicate 15 to 20 per cent increased yields by sprayed plants. (Parris)

BEANS

The Chinese rose beetle (*Adoretus sinicus*) causes appreciable reduction in the yield of beans by damage to the foliage. Two repellents, tetramethyl thiuram monosulphide and tetramethyl thiuram disulphide, and one contact insecticide, Dry Pyrocide, were applied to an experimental plat of pole beans to determine their values in the control of this insect. The repellents are sprays (2 pounds per 180 gallons water); the pyrethrum product was used as a dust. Sulphur was used as a diluent in the proportion of 1:9.

Results showed that all three materials, applied at weekly intervals, produced higher total yields than untreated check plants. However, only the disulphide and the pyrocide-sulphur gave differences within the range of significance. Approximately 50 percent of the bean crop was discarded as of nonmarketable value due either to physical defects or to the ravages of the larvae of the insect *Lycaena boetica*. When marketable pods only are considered, both of the thiuram salts gave significant increases over the check, but the pyrocide-sulphur dust produced no appreciable effect. Both of the thiuram salts decreased the damage due to *L. boetica*. Of the two thiuram salts the disulphide was the better. (Parris, Kikuta)

POTATOES

Potatoes are grown by several sugar plantations on Oahu and Kauai during the winter months for shipment to mainland States. The varieties Bliss Triumph and to a lesser extent British Queen are produced.

Scab (*Actinomyces scabies*) and *Rhizoctonia* (*R. solani*) are of economic significance in the Territory of Hawaii, and experiments were conducted during the last year to determine the best method for controlling these two diseases. Experimental areas were at Waipahu, Oahu; Waialua, Oahu; and Kilauea, Kauai. Seed dips used were mercuric chloride, formaldehyde, and yellow oxide; yellow oxide, calomel, and sulphur were incorporated with the fertilizer, the mercurials in quantities of 2 and 4 pounds per ton of fertilizer, the sulphur in quantities of 200 and 400 pounds per acre.

Results obtained were affected by variation in the disease content of the seed used, and also by soil types and environmental conditions. Consequently, different results were obtained in various localities with the same treatment.

At Waipahu, untreated tubers produced a crop with 21 percent *Rhizoctonia* and 7 percent severe scab. Seed dips were of value in reducing *Rhizoctonia* but not scab. Sulphur (400 pounds) and calomel (4 pounds) reduced the scab content by significant amounts. Yellow oxide seed dip and mercuric chloride seed dip reduced the germination by 13 and 20 percent respectively. The yield of check plants was 1.3 pounds per plant. No treatment had any effect on yield.

At Waialua, a very severe type of scab was found in 40 percent of the tubers in check plants. Mercuric chloride and formalin treatments decreased the percentage of tubers showing severe scab, but were of no value in reducing the total scab content. Other treatments had no significant effect on scab. The *Rhizoctonia* content at Waialua was low (11 percent), and no treatment reduced the percentage of *Rhizoctonia* by a significant amount except mercuric chloride, with a reduction of 9 percent. Mercuric chloride and yellow oxide seed dips retarded the germination of tubers. At 12 weeks of age this retardation was no longer evident. The high percentage of severe scab found at Waialua is thought to be partly due

to delayed harvesting of the crop. Yields averaged 0.8 pound per plant.

At Kilauea, a very high percentage (44) of *Rhizoctonia* was encountered, and 25 percent of the tubers showed severe scab. Yellow oxide dip reduced severe scab by 20 percent and *Rhizoctonia* by 32 percent. Calomel (4 pounds) and yellow oxide (4 and 2 pounds) reduced *Rhizoctonia* by 15, 12, and 12 percent, respectively. Other treatments were of no value in the control of either disease. Yellow oxide seed dip was also of benefit by increasing the germination by 9 percent. Yields averaged 0.7 pound per plant.

It is difficult to draw conclusions from these highly variable results, and the problem of the control of these two diseases is still largely unsolved for Hawaii. Future research work, if undertaken, will seek to use a single seed lot planted in a number of different localities in order to reduce the error introduced by the use of seed of variable disease content. (Parris, Kikuta)

Effect of Virus Diseases on Yield of Potatoes

Yield data were obtained on healthy Bliss Triumph potato plants, and plants affected with rugose mosaic and mild mosaic. Plants showing mild mosaic were divided into two groups—plants smaller than healthy plants, and plants showing no stunting.

Data on yield are presented in table 5.

Table 5.—Average yield of healthy Bliss Triumph potato plants and virus-diseased plants

Virus	No. of plants	Yield ± S.E.[1]	Difference in yields Healthy minus diseased ± S.E.[1]
		Grams	Grams
Rugose mosaic	16	81.6 ± 43.2	347.3 ± 61.1
Mild mosaic with stunting	13	170.3 ± 43.2	258.6 ± 61.1
Mild mosaic, no stunting	16	344.5 ± 43.2	84.3 ± 61.1
Healthy plants	86	428.9 ± 43.2	

[1] Standard error.

Plants diseased with rugose mosaic, or with mild mosaic accompanied by stunting, yielded significantly less than healthy plants. Plants with mild mosaic but no stunting yielded less than healthy plants, but the difference was not significant. (Parris)

TOMATOES

Experimental work on tomatoes has been limited to two lines of research: Testing, first, the fungicidal and insecticidal values of various sprays and dusts; and second, the effectiveness of modified standard soil treatments with chloropicrin and carbon bisulphide in the control of the root-knot nematode (*Heterodera marioni*).

A New Virus Disease of Tomatoes for Hawaii

During the past fiscal year it has been possible to obtain results on two crops of tomatoes at Waipahu, one during the period September-December 1936, and the other during the period March-June 1937. Fungus diseases have been relatively unimportant. *Alternaria* leaf spot (*A. solani*) has been present at intervals but, due to low precipitation, spraying for this disease is apparently nonessential. Fruit rots, especially of fruit in contact with the soil, have been present but not abundant. Various fungi, including the genera *Pythium* and *Fusarium*, have been isolated from rotted fruit. Virus diseases are a distinct problem in the production of tomatoes in the experimental planting. Tomato mosaic, fern-leaf (cucumber-mosaic virus) and a virus disease of the ring-spot type have caused appreciable losses.

Tomato plants infected early in their growth by mosaic or fern-leaf do not attain normal size. The relative weights of healthy plants and virus-diseased tomato plants are shown in table 6.

Table 6.—Relative weights of healthy tomato plants and plants affected with tomato mosaic or fern-leaf. Data taken when plants were 3 months old.

Plant material	Average weight of plant ± S.E.[1]
	Pounds
Healthy	5.77 ± 0.12
Diseased	2.71 ± 0.37
Difference ± S.E.[1]	3.06 ± 0.38

[1] Standard error.

The ring-spot virus disease caused an approximate mortality of 25 percent in the second experimental planting. First symptoms are small, dark, ringlike lesions on the young leaves. A border of yellowish-green color invariably surrounds the darkened areas. As the disease progresses the leaves are killed, and death of the termi-

nal growth is not uncommon. In extreme cases the entire plant gives an appearance of wilt and produces few fruit. On the fruit, definite, targetlike, nonnecrotic symptoms appear which consist of alternate bands of yellow and red color. The disease apparently inhibits the production of the red color characteristic of mature fruit. Rugosity of the surface of the fruit is sometimes found. Affected fruit are coarse of texture and of poor flavor. Bronzing is present on affected foliage and fruit.

Preliminary mechanical inoculations have failed to transmit the disease from tomato to tomato. (Parris)

Tomato Insect Pests of Major Importance

The tomato fruit worm (*Phthorimoea* sp.) and the corn earworm (*Heliothis obsoleta*) caused losses of 45 to 60 percent on unsprayed tomato plants in the experimental planting during the last year. In the first planting no spray or dust treatment gave any significant reduction in the percentage of wormy fruit. In the second planting, the treatments tried in the first planting were repeated and, in addition, several new spray treatments were included.

Four sprays gave significant reductions in the percentage of wormy fruit in the second spray and dust program. These were: (1) Coposil; (2) coposil plus 5 percent rotenone concentrate; (3) coposil plus commercial derris; and (4) tetramethyl thiuram monosulphide.

Staking of tomatoes has been recommended for Hawaii by various workers. In order to determine the value of staking, one-half of the second experimental plat was staked, and the remainder left unstaked. Results showed that at Waipahu, staked plants produced significantly less total fruit than unstaked plants. The difference varied from 5 to 20 percent depending on the treatment. On the other hand, staked plants produced 10 percent less wormy fruit, and more healthy fruit than unstaked plants.

Two other tomato insect pests are of economic significance—the melon fly (*Dacus cucurbitae*), and the Hemipterous insect *Engytatus geniculatus*. Chief damage by the latter is the girdling of young blossoms and terminals of the tomato plant. The melon fly caused approximately 5 percent loss in unsprayed plants. No data were taken on injuries due to *E. geniculatus*. (Parris)

Root-Knot Nematode on Tomatoes

The nematode *H. marioni* is one of the most serious obstacles to tomato production in Hawaii. Chloropicrin and carbon bisulphide are the recognized soil disinfestants in the control of this nematode. Results obtained from field experiments using these tried soil disinfestants in various ways and using measurements of plant stature as the growth criterion, showed that five treatments gave significant increases in height over check plants. These treatments were: (1) Chloropicrin (100 pounds per acre); (2) chloropicrin (66 pounds per acre, emulsified); (3) chloropicrin (100 pounds per acre, emulsified); (4) carbon bisulphide (450 pounds per acre); and (5) carbon bisulphide (200 pounds per acre emulsified). Mulch paper was not used. The soil was relatively moist and the use of paper was not considered necessary with the high concentrations of chemicals used per plant.

When data were calculated from the relative weights of the plants in the different treatments it was found that four treatments gave significant increases over the check, namely, (1) chloropicrin (100 pounds per acre); (2) chloropicrin (200 pounds per acre); (3) chloropicrin (100 pounds per acre, emulsified); and (4) carbon bisulphide (450 pounds per acre).

From these preliminary data it would appear that reduction in concentration of the fumigant by emulsification, a process developed by workers of the Pineapple Experiment Station, was of value in nematode abatement as measured in the present investigations. A second series of soil treatments is at present under way. (Parris)

MISCELLANEOUS FUNGUS DISEASES AND INSECT PESTS

Following is a list of fungus diseases and insect pests encountered during the past year:

Alfalfa (*Medicago sativa*)—leaf spot (*Pseudopeziza medicaginis*); rust (*Uromyces medicaginis*).

Asparagus (*Asparagus officinalis* var. *altilis*)—wilt (*Fusarium* sp.).

Bean (*Phaseolus vulgaris*)—pod spot (*Isariopsis griseola*); pod borer (*Lycaena boetica*); leaf spot (*Cercospora cruenta*).

Bird of paradise (*Strelitzea reginae*)—basal rot (*Fusarium* sp.).

Carnation (*Dianthus caryophyllus*)—leaf spot (*Septoria dianthi*).

Citrus—leaf spot (*Colletotrichum gloeosporioides*); scab (*Sphaceloma fawcettii*).

Coffee (*Coffee arabica*)—leaf spot (*Cercospora coffeicola*).

Corn (*Zea mays*)—smut (*Ustilago zeae*).

Cucurbits—hopper burn (*Empoasca solani*).

Delphinium (*Delphinium* sp.)—wilt and root rot (*Sclerotium delphinii.*)

Daikon (*Raphanus* sp.)—mosaic.

Eggplant (*Solanum melongena* var. *esculentum*)—leaf curl and stunt due to mites.

Ginger (*Zingiber officinale*)—leaf spot (*Coniothyrium zinziberi*); basal rot (*Fusarium* sp.).

Gladiolus (*Gladiolus* sp.)—corm rot (*Bacterium marginatum*).

Grasses:

Bromegrass (*Bromus catharticus*)—smut (*Ustilago* sp. [*bromivora*?]).

Dallis grass (*Paspalum dilatatum*)—smut (*Sorosporium paspali*) on imported seed.

Dallis grass (*Paspalum orbiculare*)—smut (*Sorosporium paspali*).

Rattail grass (*Sporobolus poiretii*)—*Helminthosporium ravenelii.*

Litchi (*Litchi chinensis*)—erinose (a species of mite).

Macadamia (*Macadamia ternifolia*)—blossom blight (*Gloeosporium* sp.).

Mango (*Mangifera indica*)—blossom blight (*Gloeosporium* sp.).

Onion (*Allium* sp.)—pink rot (*Phoma terrestris*); storage rot (*Bacterium* sp.); thrips (*T. tabaci*).

Pea (*Pisum sativum*)—leaf and pod spot (*Ascochyta* sp. [*pisi*?]); wilt (various fungi).

Pepper (*Capsicum frutescens*)—wilt (*Fusarium* sp.); leaf curl and stunt (mites).

Peanut (*Arachis hypogaea*)—leaf spot (*Phyllosticta* sp.)

Periwinkle (*Vinca* sp.)—blight (*Phytophthora colocasiae*).

Potato (*Solanum tuberosum*)—tuber moth (*Phthorimaea operculella*).

Rhubarb (*Rheum rhaponticum*)—leaf spot (*Phyllosticta straminella*).

Rice (*Oryza sativa*)—kernel spotting (*Halminthosporium* sp.).

Rose (*Rosa* sp.)—leaf spots (*Diplocarpon rosae* and *Phyllosticta* sp.).

Spinach (*Spinacia oleracea*)—downy mildew (*Peronospora effusa*).
Sweetpotato (*Ipomoea batatas*)—leaf spot (*Septoria bataticola*).
Sweet pea (*Lathyrus odoratus*)—mosaic; leaf spot (*Glomorella cingulata*); wilt (*Fusarium* sp.).
Turnip (*Brassica rapa*)—leaf spot (*Alternaria brassicae*).

Correction: In the 1935-36 annual report, the Mexican bean beetle (*Epilachna corrupta*) was reported from this department to be present in Hawaii. This statement is incorrect; this insect is *not* present in Hawaii. (Parris)

SOIL PHYSICS

Continued effort to improve the technique required for the determination of freezing point depressions for a typical Hawaiian soil at varying moisture contents has focused attention upon the great significance of the history of the sample prior to its introduction into the freezing tube. Repeated trials indicated that a history of rapid drying, prior to freezing, resulted in a smaller freezing point depression than would result at the same moisture content if the preliminary drying had been slow. In extreme cases, conventionally determined freezing points were above zero degrees Centigrade.

Supplemental tests indicated that inequalities of moisture content within the sample were responsible for this result. When a quickly and superficially dried sample of soil was introduced into a Dewar flask, an increase in temperature was noted in a degree sufficient to introduce the irregularities noted in the standard freezing point depression results. It would appear, therefore, that under the conditions present, the migration of moisture from the wetter fraction of soil and its absorption by the drier fraction resulted in the release of energy in the form of heat. Although it is recognized that this transfer must be small, both in rate and magnitude, its effect is marked.

Qualitative verification of this assumption was secured by mixing various proportions of damp and oven-dry soil at the same temperature. When this was done, increases in temperature were in qualitative accord with the evident energy relationships. Moreover, it was found possible to modify the temperature of a soil mass

in a vacuum flask by subjecting the soil to a slow blast of air at varying humidities. In general, subjecting the soil to a draft of moist air generated heat and the converse was also true. The magnitude of the change was rigorously conditioned by the original moisture content of the soil.

Conventional heat-of-wetting studies with samples of soil at varying moisture contents indicated that the heat generated by saturating unit mass of soil increased rapidly as the original moisture content of the soil was reduced. There is some evidence of a close correlation between a function of this energy and the conventional pF of the soil.

Opportunities have been available for a detailed study of only one soil. This is a typical lateritic soil of high clay content. Extracted colloid gave the following results from fusion analysis: Ignition loss, 17.3 percent; SiO_2, 29.8 percent; Al_2O_3, 32.1 percent; and Fe_2O_3, 19. 3 percent.

Plans are made to continue the study with other soils. The results so far obtained are now ready for publication. (Wadsworth)

CHEMISTRY AND SOILS

SOIL INVESTIGATIONS

Carbon Content of Hawaiian Soils

A critical investigation was undertaken of the methods of determining carbon content and the carbon nitrogen ratios of Hawaiian soils. The following methods of determining the carbon content of soils were used: (a) Dry combustion method; (b) wet combustion method (A. O. A. C.); (c) titration method (after Walkley). In order to obtain a successful determination using the wet combustion method, no water could be introduced into the system except that present in the chromic acid oxidizing mixture.

Results were obtained using the three methods on a series of rather varied soils. These data show a good agreement between the dry and wet combustion methods. The rapid titration method of Walkley also shows a consistent agreement, which indicates that this method would be sufficiently accurate for most observations.

A statistical investigation was made to determine if any of the soil environmental conditions, i.e., rainfall and temperature, were

related to the carbon nitrogen ratio of the soils. The results are listed.

Comparison	Regression coefficient	Standard error of coefficients
Carbon nitrogen ratio on rainfall	+ 6.70[1]	1.5
Carbon nitrogen ratio on temperature	— 0.107	0.29
Carbon on rainfall	+ 0.054[1]	0.0156
Carbon on temperature	— 0.628	0.388
Nitrogen on rainfall	+ 0.0031	0.0020
Nitrogen on temperature	— 0.0201	0.0158

[1] Probability 0.01.

These data show that soils from regions of high rainfall have high carbon nitrogen ratios, and also that the carbon rather than the nitrogen content varies with the rainfall. (Watanabe, Dean)

Soil Colloid Studies

Samples of a soil colloid $< 1\mu$ were isolated from an Ewa soil and freed from organic matter. One sample of this colloid was treated with hydrogen sulphide to remove the free iron oxide according to the method of Drosdoff and Truog; another sample was treated with successive portions of one-tenth normal hydrofluoric acid at boiling temperature in order to remove any readily decomposable silicates. These samples were then analyzed and the results calculated back to the weight of the original colloid used. The results indicate that the hydrofluoric acid treatment must have removed hydrated aluminum silicates which did not have any base exchange properties, while the hydrogen sulphide treatment removed some iron oxide as expected, but also decomposed some of the compounds having base exchange properties. (C. Lyman, Dean)

Soil Phosphorus Studies

To obtain a clearer picture of phosphorus availability in Hawaiian soils, two soils were separated into different sizes of resistant aggregates by elutriation, a resistant aggregate being defined as that aggregate which resisted dispersion when mechanically dispersed for 15 minutes in a Bouyoucos mixing machine without a dispersing agent. It was found that the fraction 0.5μ-5μ of the soils studied contained the most total phosphorus. In the largest fraction 25μ-125μ, the percentage of total phosphorus found to be in an acid soluble form, presumably as a calcium phosphate, was greater than in the smaller fractions.

Tests showed that from 4 to 8 hours of shaking with the Truog extracting agent (0.002 normal sulphuric acid at pH 3) removed the maximum amount of dissolved phosphorus, and a longer period of shaking caused a sharp decrease. Further, stirring in a Bouyoucos type of dispersing machine caused a marked decrease in the amount of available phosphorus extracted. (Dean)

COFFEE INVESTIGATIONS

The yield records of two coffee fertilizer experiments for the 1936-37 harvest were obtained for individual trees for the first time, rather than for plats (9 trees per plat). A statistical analysis of these yields was made and the standard error of the differences determined, using both plat and individual tree yields. Results are shown in table 7.

Table 7.—1936-37 yields of coffee experiments showing standard errors calculated from plat and individual tree yields

Takashiba experiment, Kealakekua, Hawaii

						Standard error of difference	
						Using plat yields	Using tree yields
Treatment[1]	8-8-8	4-8-8	8-0-8	0-8-8	8-8-0		
Yield in bags cherry coffee per acre	242 --	248 --	249 --	168 --	130 --	25.2	18.1

Fukuda experiment, Kainaliu, Hawaii

						Standard error of difference	
						Using plat yields	Using tree yields
Treatment[1]	8-8-8	8-0-8	8-8-0	8-0-0	0-0-0		
Yield in bags cherry coffee per acre	74	75	12	11	16	12.4	6.5

[1] 2,000 pounds fertilizer applied per acre per year with formulas shown. The plant food in a 4-8-8 treatment consisted of 80 pounds nitrogen, 160 pounds phosphorus pentoxide, and 160 pounds potash. Sources of plant food were: Nitrogen, one-half from ammonium sulphate, one-half from sodium nitrate, phosphoric acid from superphosphate, and potash from potassium sulphate.

These data indicate that, in both experiments, the errors calculated from individual yields were considerably less than from plat yields. This was especially true in the case of the Fukuda

experiment. It is of interest to note that in the Takashiba experiment the difference between the 0-8-8 and 8-8-0 plats is not significant when the standard error calculated from plat yields is considered, but is significant when using the standard error calculated from individual tree yields. (Edwards, Ripperton, Fukunaga, Dean)

THALLIUM DETERMINATION IN RAT BAITS

In conjunction with the manufacture of thallium-containing baits for the rat abatement program, it was necessary to make analyses of the thallium contents of the baits to test uniformity of mixture. Since the baits were manufactured from animal products, it was necessary to develop a simple method of analysis for thallium in the presence of iron. The method developed involved the destroying of the organic material by wet oxidation with nitric and sulphuric acids, and the precipitation of the thallium as the iodide from the solution neutralized to pH 4. This method allowed an operator to obtain an accurate estimate of the thallium content of the rat baits in about one day's time (Togashi, Watanabe, Dean)

THE HYDROCYANIC ACID CONTENT OF HAWAIIAN-GROWN CASSAVA

A series of analyses of the cassava varieties produced in Hawaii was made in order to determine their contents of hydrocyanic acid. These analyses showed that the 14 varieties submitted ranged from 40 to 365 milligrams hydrocyanic acid per kilogram of fresh material. A study of the hydrocyanic acid content of various products prepared from cassava revealed that in some instances it was necessary to add a glucoside-splitting enzyme in order to obtain a successful analysis. Further, it was shown that the commercially obtainable glucoside-splitting enzyme emulsin was not capable of completely splitting hydrocyanic acid from the cassava glucoside. (Dean)

TARO PROCESSING

Taro Analyses

The initial investigations of the taro processing laboratory were summarized in the station's annual report for 1936. This preliminary work revealed the possibilities of preparing commercially a variety of products from taro, chief among which were flour, cereals, and beverage powders. Further progress along these lines

has provided a considerable body of technological data, particularly as regards the manufacturing technique of flour and products baked therefrom, and the production of beverage powders. The laboratory has concurrently completed a series of analyses, both organic and inorganic, of flours produced from four commercial varieties of taro.

The samples of flour analyzed were produced in the manner employed in the semicommercial pilot plant operations, except that additional precautions were taken to avoid metallic contamination. Two of the taro varieties, namely Piialii and Haehae, were of the so-called wet-land group, or those taros which are grown submerged. The other two, Palaii and Mana Opelu, were upland taros, grown either with or without irrigation but not submerged. All analyses, as given in tables 8 and 9, have been calculated on the dry basis.

Table 8.—Organic analysis of taro flour from wet-land variety, Haehae (results calculated to air-dry basis)

Constituent	Percentage
Moisture 70°-75° C. vacuum	7.75
Ash	1.55
Protein	2.00
Ether extract	0.56
Crude fiber	1.42
Starch	77.91
Reducing sugars	0.52
Sucrose	0.11
Pentosans	2.58
Dextrin	0.52
Total	94.92

Table 9.—Inorganic analysis of taro flour from wet-land variety, Haehae (results calculated to air-dry basis)

Constituent	Percentage
Ash	1.55
Calcium	0.089
Chlorine	0.0693
Copper	0.0003
Iron	0.0043
Magnesium	0.082
Manganese	0.0010
Phosphorus	0.149
Potassium	0.408
Sodium	
Sulphur	0.0147
Zinc	0.00010
Acid base balance[1]	19.07

[1]Cubic centimeters of normal acid required to neutralize 100 grams of ash.

Method of Flour Production

The cooked taro corms were peeled, washed, and ground in an attrition mill to a pasty mass identical with the product known as poi (figure 8). Possibly the most significant discovery in connection with the flour-processing investigations was of a change, under certain temperature conditions, of the physical state of poi from a highly viscous paste to a solid, rubbery mass. This change resembled the setting which occurs in gelatin solutions, and was most effectively brought about at temperatures ranging from 32° to 40° F. In no instance was it possible to effect a complete setting of the paste in less than 24 hours. The rapidity of setting was further found to bear an inverse relationship to the moisture content of the taro, which may vary from about 60 to over 70 percent.

The solidified masses are porous and devoid of stickiness; they can be sliced or shredded mechanically, and in such forms the material lends itself readily to drying in cabinets by exposure to currents of heated air. Drying to a final moisture content of not over 10 percent can be effected in a period of 6 hours. The initial temperature must not exceed 150° F., in order to avoid stickiness, but can gradually be brought up to a temperature of 200° F.

The dried shreds or slices were ground in a hammer mill operated in circuit with a gyratory sifter. A silk screen of about 0.01-inch mesh has been found to produce the most satisfactory flour for general use.

Baking Investigations

Additional bread-baking studies were conducted throughout the year on a commercial scale through the cooperation of United States Army and commercial bakeries. The main purpose of these tests was to develop formulas best suited to blends of taro and refined wheat flour. Among other factors considered in rating formulas was the continued acceptance of the taro-wheat bread over an extended period of time, when distributed through the regular commercial channels.

With the use of from 15 to 20 percent of taro flour (total flour used taken as 100 percent) it was found possible to obtain loaves which were in every respect like ordinary white bread except as to color of crumb. The color of the crumb of the taro-wheat bread is

considerably darker than that of white bread, but volume, texture, and general appearance of loaf are identical. The flavor of the taro-wheat bread is distinctive and is generally regarded as highly palatable.

Figure 8.—Shredding refrigerated poi. Note the cheeselike nature of the refrigerated poi on left. When shredded, this material can be dried without case hardening or having the shreds stick together.

The absorption of taro-wheat blends is considerably higher than that of white doughs. An increase of 1 percent (pounds of water per pound of flour) is gained for each 1 percent of taro flour used. The Army bakeries, using 15 percent taro flour, reported an increase in absorption of 16 percent. Due to this increased water content, taro-wheat bread remains fresh much longer than ordinary white bread. Only half the customary amount of sugar is needed, since taro-wheat bread takes on color in the oven more quickly than does white bread.

The following formula, with usual procedure and time of fermentation, has been found to give excellent results:

Taro flour ..... 15 to 20 pounds	Total flour—100 pounds
White flour ..... 85 to 80 pounds	
Sugar	1 pound, 3 ounces
Salt	2 pounds, 6 ounces
Shortening	1 pound, 3 ounces
Compressed yeast	1 pound, 13 ounces

BEVERAGE POWDER STUDIES

The object of these investigations was to prepare taro, either plain or flavored, in a dried form which would dissolve readily when shaken or beaten with cold milk or other liquids. Three methods of drying were investigated, namely: (a) Air drying, as described above; (b) spray drying; and (c) drum drying.

The air-dried product was found unsatisfactory, due to the fact that it did not dissolve readily in cold liquids, even when reduced to a very fine powder. The spray-dried powders, which are of exceedingly fine mesh due to the nature of the drying process, proved difficult to dissolve because of lumping. Through drum drying, on the other hand, it was found possible to produce finely flaked powders which dissolve readily when shaken with liquids in a closed jar, or when beaten with an egg beater. The term "dissolve" is here used in the commercial sense, signifying not true solution but a colloidal dispersion of the dry material in the liquid.

The method of preparation was as follows. The cooked taro was first converted into poi as in the preparation of flour. This material, either with or without the addition of sweetening and flavoring materials, was mixed in a commercial slow-speed mixer with enough water added to reduce the total solids to not over 20 percent. At this concentration the mixture flowed freely, and was fed between the drums of a double drum drier, the drums of which were heated internally by steam at pressures varying from 65 to 75 pounds. The dried material came off the rolls in large thin flakes or sheets which were mechanically reduced and sifted through a wire screen of about 0.05-inch mesh.

Three satisfactory drum-dried beverage powders have thus far been developed. The first contains 40 percent taro (dry basis) and is flavored and sweetened by the addition of cocoa, sugar, salt, and malt sirup. The second is entirely unsweetened, being flavored only by the addition of small quantities of salt and malt sirup. The taro content of this product is 96 percent. A third product consists of pure taro, without the addition of any other ingredients. (Ley, Payne, Edwards)

STEROLS OF TROPICAL OILS

The studies described in the annual reports of the station for 1935 and 1936 of the sterols of tropical oils, namely, avocado, kukui nut, coconut palm, china-wood, and chaulmoogra, were continued. Progress was made particularly along the following lines of investigation:

Using methods described in previous reports, avocado sterol was prepared and purified by freezing out the sterol fraction from a 4 to 1 methyl alcohol-ethyl alcohol mixture at –60° C. in a bath of carbon dioxide ice and ether. Kukui nut, china-wood, and chaulmoogra sterols were purified by crystallization from alcohol solutions which had been treated several times with norite. Coconut sterol was purified by precipitating its digitonide and recovering the sterol by acetylation. While the yield of sterol was relatively low, this method proved to be more satisfactory than any other for purifying coconut sterol.

To separate from each other closely related sterols which differ primarily with respect to degree of unsaturation, bromacetates were prepared and separated by fractional precipitation. They were then reduced to acetates by zinc dust and acetic acid in alcoholic medium and saponified. The separated sterols were purified by treatment with norite and recrystallization from alcohol. Yields were not quantitative.

A 10-gram sample of each oil was used and a quantitative, comparative study of the 5 oils was made for the purpose of determining for each the percentage of unsaponifiable matter, percentage precipitated by digitonin, percentage of sterol present, and molecular weight. Results obtained are given in table 10.

Table 10.—Quantitative analysis of the sterol contents of tropical oils

	Avocado	Kukui nut	China-wood	Chaulmoogra		Coconut
				Local	India	
Unsaponifiable (Percent)	1.81	0.69	0.59	0.61	0.52	0.25
Precipitated by digitonin (Percent)	57.63	39.13	37.30	41.77	32.82	35.13
Sterol in oil (Percent)	1.05	0.27	0.22	0.25	0.17	0.09
Molecular weight[1]	364	365	365	394	.....	394

[1] Molecular weight determined by the camphor-fusion method.

It was found, in agreement with the literature, that sterols from the above oils contained at least two components differing from each other in degree of unsaturation. The component having the lower melting point crystallized first from the solvent and showed a smaller specific levorotation than the component remaining in the mother liquor. Table 11 shows the melting points and corresponding specific rotations.

Table 11.—Melting points and specific rotations of tropical sterols

Sterol from oil of—	Component first crystallized		Component from mother liquor	
	Melting point	$[\alpha]_D^{25}$	Melting point	$[\alpha]_D^{25}$
	°C.		°C.	
Avocado	137.5	—21.26	141.6	—23.77
Avocado	136.5-137.5	—24.39	140.6-142.6	—27.58
Kukui nut	128.0-130.1	—21.97	130.1-131.7	—24.80
China-wood	132.1-134.3	—19.17	130-136	—22.71
Chaulmoogra	130.1-136.4	—21.83	140.0	—27.83
Coconut	121.5-123.8	—21.21	.....	.....

The number of hydroxyl groups in each sterol was determined by acetylating the purified sterol, hydrolizing the actetate, and determining the equivalent weight by indirect titration. The results lead to the conclusion that each sterol molecule contained one hydroxyl group. This is in agreement with the literature describing phytosterols. (L. N. Bilger, M. Westgate)

IODINE CONTENTS OF HAWAIIAN MEATS AND POULTRY

The studies described in the annual reports for 1933, 1934, 1935 and 1936 were continued and the investigation extended to meats and poultry.

Meats and poultry of territorial origin were analyzed; some of the results are given in table 12. These values, as would be expected from an island region, are much higher than for many mainland localities. (E. M. Bilger)

Table 12.—Iodine contents of island meats and poultry in parts per billion of dry weight

Material	Iodine Content
Beef (round steak)	412
Beef brain	9,655
Beef heart	1,010
Beef kidney	94
Beef liver	573
Beef lungs	11,650
Chicken (hen)	5,885
Chicken heart (hen)	6,100
Chicken (14 months)	881
Duck	584
Duck gizzard	5,335
Duck heart	4,460
Pork leg	5,735
Turkey	474
Turkey gizzard	3,590
Turkey heart	8,600
Turkey liver	2,635
Veal	2,200

PAPAIN AND BROMELIN

Papain is the mixture of protein-digesting enzymes that occurs in the latex of *Carica papaya*. The consumption of papain in the United States is increasing, and it is a fair estimate that present importation is about 200,000 pounds per year, valued at approximately $1 per pound. The industry is thus a very small one, but shows signs of becoming larger.

There is no domestic preparation of papain in the United States, although the papaya grows in four localities, Puerto Rico, Canal Zone, Florida, and Hawaii. The process of preparation is too laborious to be profitable. It consists of collecting and drying the latex that exudes when a cut is made in the green papaya fruit hanging on the tree. The latex is collected from the same fruit on

several occasions a few days apart, until the yield ceases to be profitable. The dried latex is crushed and screened to remove some extraneous material, and then placed on the market. Papain should be sold on the basis of its enzyme content, but probably this is not often done. The lighter colored and less odor-bearing preparations are usually most highly valued.

It was believed that it might be possible to substitute modern apparatus and technical processes for the manual labor used in the Orient, and obtain papain from the papaya plant, and the presumably similar bromelin from pineapple wastes, at economical prices. The Bureau of Chemistry and Soils, U. S. Department of Agriculture, cooperated with the Hawaii Experiment Station in this problem, sending its foremost enzymologist, A. K. Balls, to the Hawaii Station for the period from March 1 to May 8, 1937, to work on this problem.

Papain obtained from Hawaiian-grown papaya fruits was of good quality with yields of dried latex equal to about 0.1 percent of the weight of the fruit, irrespective of the quantity of wet latex secured.

The fruit juices are very destructive to the enzyme in the latex, and attempts to macerate the fruit and extract the enzyme were negative. In bleeding the fruit for latex, fruit juices probably cannot act upon the latex as it is separate from the vascular system. Further experimenting showed, however, that the enzyme-containing latex is present not only in the fruit but also in the entire plant structure above ground. Leaves, stalks, flower stems, and bark all yielded enzyme-containing press juices; the roots yielded none. Latices from young plants and from mature male trees were also found to be rich in papain. Furthermore, the press juice of leaves and stalks appeared to contain less of the inhibitory or destructive substances than that of the fruit. The possibility exists, therefore, of recovering the enzyme from the leaves and stalks, even of the otherwise useless male trees.

There is very little difference in the quality of the juice from leaves of different ages on a mature tree, but there is a great difference in the quantity of juice to be obtained. The leaf juice obtained in the sepro-sieve apparatus is a thick green liquid full of solid particles of tissue. Seventy grams of average leaf tissue gave

25 cubic centimeters of this juice. After centrifugation, 21.5 cubic centimeters of clear press juice were obtained. The yield is thus about 30 percent of the weight of the average leaf tissue. Not only will this figure vary with the plants used, but it will also vary with the type of apparatus employed for extraction. With suitable machinery, the yield should be from one-tenth to one-fifth higher.

Clarification of the juice and inhibition of the oxidizing processes by which the enzyme is inactivated are both aided by increasing the acidity to pH 4.0 with strong acids, namely, sulphuric, hydrochloric, or acetic.

The acidified filtered juice contains about 6 percent solid matter, including 2.6 percent of substances reducing Fehling's solution, calculated as dextrose. Total nitrogen is 0.32 percent of the juice, which is equivalent to 2 percent protein. The solid matter in the clarified juice behaves analytically as though it were about half protein and half sugar. The juice also contains some of the yellow-red plant pigments and—when made from the leaves—traces of the alkaloid carpain. This last gives it a bitter taste.

Once acidified and centrifuged, the juice loses its milk-clotting power very slowly. The juice may also be filtered through paper, charcoal, or kieselguhr without material loss.

Three methods for preparation of enzyme from the acidified and clarified press juice were tried. They were:

(1) Evaporation in a vacuum at 50° C., which yielded a yellow-green powder, completely soluble in water, containing all the enzyme activity of the original. The product was of low grade because of many impurities. Removal of some of these impurities was achieved by dialysis before evaporation and washing of final product with alcohol.

(2) Precipitation with alcohol—the principle here was to separate the enzyme from the liquid by addition of alcohol. Five volumes of 92 percent alcohol gave a good yield. The enzyme deteriorated on standing in alcohol solution. For this method to be economically feasible, the alcohol must be recovered.

(3) Precipitation with ammonium sulphate which, like alcohol, will precipitate the enzyme-containing proteins from the clarified leaf juices. Two volumes of saturated ammonium sulphate to one volume clarified juice were used.

These investigations have been only introductory, but they point the way for a possible commercial enterprise. Much work remains to be done on refinements of these methods, including method of extraction, method of growing and harvesting for maximum enzyme yield, and other possible greater purification of the final product. Costs of production of enzyme by such technical methods are not yet known, but rough calculations indicate that such costs may not be excessive.

Preparation of Bromelin

Bromelin is the proteolytic enzyme of the pineapple plant, found to exist in the fruit, leaves, and stalks. The roots were not tested. Bromelin has been reported to be the same as papain—they are certainly quite similar, but since both are mixtures of several enzymes it is not to be expected that any two bromelin samples or two papain samples will be exactly the same. Their properties will vary with the proportion of the individual enzymes in the mixture. It is still less likely that preparations from such different plants as pineapple and papaya will be identical. It cannot be taken for granted that bromelin and papain are mutually replaceable, but it is evident that in some cases they are sufficiently similar to be interchanged. If bromelin were manufactured in quantity, it might be necessary to find a separate market. There is no commercial use of bromelin at present, and therefore no way of deciding if it has any special industrial importance.

The concentration of bromelin in the pineapple plant and fruit is low compared to that of papain in the papaya plant. Bromelin does not disappear in the ripe fruit, and in the pineapple cannery follows the juice. Apparently the only method remotely feasible for obtaining bromelin commercially would be that of precipitating the bromelin from the juice with alcohol and recovering both alcohol and juice for other purposes.

The work on papain and bromelin is being continued by Dr. Balls in his laboratory at Washington, with particular emphasis on the nature of these products and their further purification. (Balls, R. R. Thompson, Jones)

FOODS AND NUTRITION

THE NUTRITIVE VALUE OF FILIPINO FOODS

The nutritive needs of all racial groups living in Hawaii are very similar, although they may be supplied by quite different foods. If some of the foods peculiar to different racial groups have a high nutritive value, their use should be encouraged by other races. In order to assess the nutritive values of various foods not commonly found in the American diet, it is necessary to test the foods scientifically by chemical and biological means. The work of gathering information on the nutritive value of Filipino foods has been undertaken by the station. Such information has not previously been available, yet there are about 52,000 Filipinos in the islands, constituting approximately 13 percent of the total population of the Territory.

A list of more than 80 fruits and vegetables commonly used by Filipinos has been prepared, giving the English, Filipino, and scientific names. Many of the vegetables are common ones, used by other national groups, but some are characteristically Filipino, for example: Camongay (*Moringa oleifera*), of which the leaves and pods are used; ampalaya (*Momordica charantia*), of which the tender leaves and shoots as well as the fruit are used; sitao (*Vigna sinensis*); and saluyot (*Hibiscus esculantus*). Chemical analyses and vitamin assays of some of these Filipino foods are now in progress. The camongay leaves, compared with other green leaves, show remarkably high percentages of protein (9.4 percent [N $\times$ 6.25]) and of calcium (0.364 percent). As these leaves are so highly esteemed by the Filipinos, it will probably be a good plan to analyze other samples to learn if all have a similar composition.

Filipinos have planted the camongay or horseradish tree about the camps in some sections of the Islands. The tree is hardy and grows well in this climate. Because of its value as a food plant, additional plantings should be encouraged. The green pods of this tree, which are called "drumsticks," are very highly prized as a vegetable by the people of central and southern India.

Shown in table 13 are the results of preliminary experiments using the rat feeding method to determine the vitamin values of 6 vegetables much used by Filipinos. Additional experiments using the international standards for comparison will establish definite, average values. (Miller, Potgieter, Robbins)

Name of plant			Comparative values as sources of:		
Filipino	English	Scientific	Vitamin A	Vitamin B	Vitamin G
Sitao	Cowpea	*Vigna sinensis*	Good	Good	Good
Ampalaya (tender leaves and shoots)	Bitter squash	*Momordica charantia*	Excellent	do	do
Ampalaya (fruit)	Bitter squash	*Momordica charantia*	Fair	Fair	
Camote (tender leaves and shoots)	Sweetpotato	*Ipomoea batatas*	Excellent	Good	do
Cardis (cooked, shelled peas)	Pigeonpea	*Cajanus cajan*	Good	do	
Camongay	Horseradish tree	*Moringa oleifera*	Excellent	do	

Table 13.—Vitamin values of Filipino foods (preliminary studies)

THE NUTRITIVE VALUE OF TARO

The vitamin B (B_1) content of taro flour (made from Haehae taro by the taro-processing laboratory) was found to be approximately 0.9 international units per gram, or about 25 units per 100 calories. Thus, in addition to providing calories, taro flour contains an adequate amount of vitamin B, since man's requirements of this vitamin have been estimated to be from 20 to 30 units for each 100 calories consumed. Since vitamin B is stable under the conditions of temperature, pressure, and pH of taro flour manufacture, it is reasonable to assume that poi contains as much of the vitamin per 100 calories, and that a diet high in poi is not apt to be lacking in vitamin B.

Confirmatory tests on the vitamin C value of Japanese taro (*Colocasia esculenta*) indicate that even as much as 15 grams of steamed taro per day for 3 weeks does not protect a standard guinea pig from very evident gross scurvy. However, the scurvy in these cases is not as severe as in the case of pigs receiving no vitamin C, indicating the presence of a definite although very small amount of the vitamin in steamed Japanese taro. As a result of comparison with animals receiving various levels of ascorbic acid, the international standard vitamin C, it seems that the taro contains about 0.03 to 0.05 milligram of the vitamin per gram of taro. Taro, even when eaten in large quantities, cannot contribute more than a relatively small amount of a person's daily vitamin C requirement. (Potgieter, Takase)

ANEMIA STUDIES

Information regarding the changes that take place in the blood and the blood-forming organs of the body during recovery from anemia has been obtained from experimental work with anemic rats. Anemia can be induced in young rats by feeding them an exclusively milk diet for from 5 to 7 weeks. Recovery from the anemia can be brought about by the addition of adequate quantities of copper and iron to the milk diet, normal blood conditions being regained in from 14 to 21 days. Former studies have shown that the normal cellular constitution of the blood is established by the end of the first week of recovery and that, subsequent to that time, no changes occur. The greatest changes of the cellular ele-

ments occur on the second and the fifth day of recovery. Histological studies have shown no apparent changes occurring in the blood-forming organs, and it would seem that if such changes do occur, they would possibly be found before the first marked changes of the blood elements.

This report covers studies of the changes of the blood and blood-forming organs occurring during the first 48 hours of recovery. Fifty-nine animals were made anemic by being fed an exclusive diet of milk and were then fed copper and iron (daily quantities of 0.5 milligram iron and 0.25 milligram copper) to induce recovery. Seven animals were killed as negative controls while the remaining animals were killed at various intervals from 2 to 48 hours following the feeding of the copper and iron. Hemoglobin studies showed that during the first few hours of the recovery period, no changes of this blood element occurred, but that 24 hours after feeding it was found to have increased a gram or a fraction of a gram per 100 cubic centimeters blood, and at 48 hours, 1.5 to 2.0 grams. Increase of the erythrocytes was found to be very irregular but by the end of the 48 hour period an increase of 800,000 to 1,000,000 cells per cubic millimeter blood had occurred. The number of leucocytes increased to 15,000 to 32,000 at 24 hours, 22,000 to 38,000 at 36 hours, and 23,000 to 38,000 at 48 hours. Changes in the number of blood platelets were very irregular, increasing in number in some animals while decreasing in others.

Histological studies of the bone marrows of the animals showed that in general no changes occurred during the first 18 hours of recovery. Changes were very marked at 20 to 24 hours, the marrow at this time being packed with the early stages of the red blood cells. From 24 to 48 hours the immature red cells were found to mature as well as to take part in the homoplastic formation of additional red cells. The time of appearance of the first stages of erythrocyte formation appears to depend on the severity and the character of the anemia that existed before the feeding began. The condition described above occurs in moderately anemic animals; neutrophile formation also is extensive in severely anemic animals. Fatty infiltration of liver was found to occur to a variable extent in all anemic animals. This condition disappeared on copper and iron feeding. The study of the extent to which the liver, lymph nodes,

and spleen are involved in blood cell formation during the first 48 hours of recovery has not been completed. However, enlargement of the spleen occurs, reaching its greatest size at about 48 hours, an observation which confirms former studies. (Hamre, Louis)

TRUCK CROP MARKETING

Estimates of truck crop production for the coming month have been prepared and mailed out by the first of each month during the past fiscal year. These monthly surveys list estimated production of 31 commodities, by islands, and in addition estimate the quantity which will be available where grown, and the percentages available for the Honolulu market, and for shipment to mainland United States. The commodities thus covered are as follows: Asparagus, green string bean, beet, topped beat, broccoli, burdock, Chinese cabbage, head cabbage, cantaloup, carrot, topped carrot, green corn, cucumber, long eggplant, round eggplant, head lettuce, lotus root, bulb onion, papaya, bell pepper, red potato, sweetpotato (Nancy Hall), sweetpotato (all others including yams), white potato, pumpkin, summer squash, upland taro, wet-land taro, tomato, egg tomato, and watermelon.

The monthly crop estimates have been prepared in cooperation with the Agricultural Extension Service and have been mailed to a steadily growing list, comprising 727 persons as of June 1937, of which number approximately 62 percent were growers. Funds from the truck crop project for financing these estimates were depleted before the end of the year, but arrangements were made to continue the work for the full fiscal year. The 1937 Legislature of the Territory of Hawaii passed Act 205, which appropriated $30,000 for continuing the surveys during the ensuing biennium. This work will, therefore, be maintained and monthly crop estimates sent out by the Agricultural Extension Service.

A review of the work on marketing in the truck crop project, together with a digest of the data in the 1936 Census and 1936-37 monthly estimates, will be published in a bulletin of the experiment station. These data will be very fruitful for further statistical investigations. They have already indicated that the actual acreage devoted to commercial production of the commodities listed in the truck crop estimates averages almost 3,050 acres, or approximately

1 percent of the total arable land in the Territory. Production was estimated equal to 5,303,800 pounds for the year, with a value of about $1,844,340. (Cady, Frazier)

ANIMAL HUSBANDRY

DAIRY

At the close of the fiscal year the dairy herd consisted of 46 Holsteins and 16 Guernseys. These are maintained at the university farm to provide livestock for research work, as well as study material for students in dairy husbandry.

Tests made during the year showed the herd to be free from tuberculosis and contagious abortion. A program designed to eradicate liver fluke is under way.

Sesame Meal Equal to Soybean Oil Cake Meal for Dairy Cows

In two 12-week experiments, each with 6 cows, sesame oil cake meal proved fully as valuable as soybean oil cake meal as measured by milk production, body weight, and butterfat content of the milk. These experiments confirm the results of an earlier experiment previously reported. In all of these tests these meals, which constituted 20 percent of the total concentrate ration, were used as protein supplements to rations which were the same in all other respects. (Henke, Goo)

Molasses Added to Roughage Increases Milk Production

In a third 12-week experiment with 6 cows, the addition of 4 pounds of cane molasses poured over the roughage to rations otherwise the same in quality and quantity increased milk production by 4.5 percent, and the molasses utilized in this way, with milk selling at 7 cents per quart, was worth $17.50 per ton in the form of added milk produced. The cows averaged 11 pounds greater live weight when the molasses was added to their ration, but butterfat tests were slightly lower.

The results of this experiment are in accord with two previous similar experiments, average milk production being 6 per cent higher, live weight averaging 14 pounds greater, and average butterfat tests being 0.06 percent less when the molasses was added to the

roughage. These results would indicate that pouring cane molasses over the roughage fed to dairy cows is a desirable and profitable practice in Hawaii. (Henke, Goo)

Value of Algaroba Bean Meal for Dairy Cows

In one 12-week experiment with 8 cows a control ration containing 45.4 percent pineapple bran, 36.4 percent soybean oil cake meal and 18.2 percent cane molasses was compared with an experimental ration containing 40 percent algaroba bean meal, 30 percent soybean oil cake meal, 20 percent cane molasses, and 10 percent pineapple bran. While live weights of the cows and butterfat percentages were about the same on the two rations, milk production was 4 percent greater on the control ration. Assuming a value of $25 per ton for the algaroba bean meal (this feed does not have a definite market value), with other feeds at prevailing prices, milk production costs were 14 percent greater when the algaroba bean meal mixture was fed. (Henke, Work, Goo)

Green Sudan Grass Slightly Superior to Green Panicum Grass for Dairy Cows

In a 12-week experiment with 8 cows, green Sudan grass was 9 percent more palatable than green Panicum grass, as measured by amounts consumed, and milk production averaged 5 percent higher for the cows receiving the former roughage. The live weight of the cows and the butterfat content of the milk were essentially the same with both grasses. In this test, the only variable was the green roughage; the same amounts of the same concentrate ration were fed in both cases. (Henke, Goo)

BEEF CATTLE FEEDING EXPERIMENTS

Koa Haole Pasture (*Leucaena glauca*) versus Koa Haole Pasture Supplemented with Cane Molasses for Fattening Beef Cattle (Waianae experiment)

This was a cooperative experiment carried on with Waianae Company, Ltd., who furnished the steers, pasture, and supplementary cane molasses. A 60-acre koa haole pasture was divided into two 30-acre areas and 15 Aberdeen Angus steers having an average initial weight of 639 pounds were put in each pasture. Supplementary cane molasses in a trough was supplied to the

steers in one pasture. The test was continued over 246 days from July 29, 1936, to April 1, 1937, inclusive.

A total of 47.79 inches of rain fell in the pasture area during the period of the experiment. Except for the first two months, when rainfall was limited, this was ample for a good growth of koa haole.

The results of this test follow (table 14):

Table 14.—Plan and results of Waianae steer fattening experiment

	Lot A (koa haole pasture only)			Lot B (koa haole pasture and cane molasses)		
	First period	Second period	Total	First period	Second period	Total
Days on test	140	106	246	140	106	246
Average initial weight (pounds)	640	812	640	638	848	638
Average final weight (pounds)	812	924	924	848	1005	1006
Average total gain (pounds)	172	112	284	210	158	368
Molasses consumed per steer daily (pounds)	.....	.....	.....	4.19	2.94	3.67
Average daily gain (pounds)	1.23	1.06	1.15	1.50	1.49	1.50

This table shows that the steers having free access to molasses made more consistent gains throughout the trial. The greater average daily consumption of molasses during the first period can, in part, be attributed to lack of browse due to small amount of rainfall. Throughout the experiment the steers on the molasses supplement had a sleeker and smoother look than those without the additional feed.

A high return was received for the molasses used. Calculations show that these Angus steers actually returned, in the form of increased beef, $17.60 per ton for the molasses fed them.

The results of the slaughter tests showed little or no difference in the chilled carcass grade. However, when rib cuts from selected animals of each group were physically examined, there could be no question but what the molasses-fed steers actually carried more intramuscular (marbling) and external fat. This information is presented in table 15.

Lot	Pasture and supplement	Weight of various portions				Measurement of portions			
		Bone	Fat	Rib eye muscle	Other lean	Eye		External fat thickness	Thickness of fat above eye muscle
						Length	Width		
		Pounds	Pounds	Pounds	Pounds	Inches	Inches	Inches	Inches
A	Koa haole only	0.97	1.65	1.50	1.88	4.33	2.36	0.39-0.79	0.39
B	Koa haole and molasses	1.00	2.00	1.50	1.50	5.25	2.25	.25-1.00	.25-.50

Table 15.—Average proportion of separable lean, fat, and bone in tenth and eleventh ribs of animals in each group

Rib cuts of superior marbling are believed to be more tender and palatable since more of the juices are preserved in cooking.

Briefly summarized, the salient results of this trial were as follows:

(1) The average daily gain of grade Angus steers on koa haole pasture was 1.5 pounds when allowed free access to molasses, as compared to 1.15 pounds for similar animals without a molasses supplement.

(2) The steers receiving molasses paid for it at the rate of $17.60 per ton (in terms of extra beef produced).

(3) Stocking koa haole pasture at the rate of 2 acres per steer in no way depleted the range when rainfall was adequate.

(4) No marked differences in carcass grade were noted between the two lots. However, physical measurements showed that the molasses-fed steers carried more fat and showed more marbling of the rib eye. (Henke, Work, Burt)

GRASS VERSUS PIGEONPEA (*Cajanus cajan*) PASTURES, AND VALUE OF SUPPLEMENTARY CANE MOLASSES AND PROTEIN SUPPLEMENTS FOR FATTENING BEEF CATTLE (Kapapala experiment)

This cooperative experiment with Kapapala Ranch was started June 13, 1936, and continued a total of 179 days to December 8, 1936, inclusive. Rainfall during this period totaled 19.63 inches; very little rain fell in June or July, but after that, particularly in August, September, and October, the precipitation was adequate.

The experiment was started with 71 Hereford steers about 14 months of age and having an average initial weight of 591 pounds (figure 9). These steers were divided into 3 groups and further subdivided into 6 different lots to test out the value of supplementary feeds. The details of these tests are shown in tables 16 and 17.

Based on the value of the increased beef resulting, molasses had a ton value of $12.80 in the case of lot I-B (pigeonpea pasture) and $9.40 in the case of lot II-B (grass pasture). The addition of soybean oil cake meal in lot II-C and fish meal in lot III-A resulted in somewhat greater gains but these increases were not sufficient to pay for the cost of the protein supplements used.

While the beef value of the molasses fed was less than in the Waianae experiment, the returns for the molasses used in this way

Group	Kind of pasture	Lot	Supplementary feed	Number of steers in lot	Area of pasture	Average initial weight	Average final weight	Average daily gain per steer
					Acres	Pounds	Pounds	Pounds
I	Pigeonpeas	A	None	16	21	589.6	876.9	1.60
		B	Cane molasses	16[1]	21	588.3	919.8	1.85
II	Improved grasses	A	None	9[2]	17	599.1	871.6	1.52
		B	Cane molasses	9	17	590.0	899.2	1.73
		C	Cane molasses and soybean oil cake meal	9	17	586.0	902.8	1.77
III	Poorer grasses		Cane molasses and fish meal	12[3]	80	600.0	928.5	1.83

[1] Two steers in this lot died soon after the start of the experiment.
[2] One of these steers died September 27.
[3] One steer slaughtered November 24 to note flavor of meat.

Table 16.—Plan and results of Kapapala beef fattening experiment

Group	Lot	Supplementary feeds consumed—						Average dressing percentage	Average price received per pound dressed weight	Average carcass value
		Per steer per day—			Per pound gain—					
		Cane molasses	Soybean oil cake meal	Fish meal	Cane molasses	Soybean oil cake meal	Fish meal			
		Pounds	Pounds	Pounds	Pounds	Pounds	Pounds		Cents	Dollars
I	A							52.25	16.63	76.18
	B	4.39			2.37			53.06	16.68	81.68
II	A							50.73	16.50	73.99
	B	6.08			3.52			52.36	16.66	79.85
	C	3.78	1.53		2.18	0.87		54.54	16.92	83.33
III	A	5.35		0.78	2.89		0.42	51.03	16.58	79.67

Table 17.—Effects of supplementary feed consumption on carcass weight and value

were far greater than if the molasses had been shipped to the mainland as is the common practice.

Of the 64 carcasses graded, only 4 were classified as better than "medium." However, this was due not so much to lack of finish as to lack of conformation. Photographs of the eleventh rib show that there was a definite increase in the surface covering of fat of the steers that had been fed supplementary cane molasses, and with additional protein supplements there were an even greater fat covering and some indications of better marbling (figure 10).

Figure 9.—Weighing steers in Kapapala experiment; grass pastures on left, pigeonpea pastures on right.

Briefly this trial indicates that:

(1) Supplementing pastures (pigeonpeas or grasses) with cane molasses results in a great gain, a better carcass, and a good return for the molasses used.

(2) Protein supplements in addition to the molasses produce only slightly higher gains than molasses alone, and these gains are insufficient to pay for the cost of such supplements.

(3) Steers on pigeonpea pasture, as compared with grass pasture, make better gains only during the time when pigeonpea pods are available.

(4) Fish meal in the quantities consumed in this experiment does not produce an undesirable flavor in the beef.

(5) The rate of stocking the pigeonpea and grass pastures in this experiment did not deplete these crops when the rainfall was adequate. (Henke, Work, Burt)

Figure 10.—Kapapala feeding experiment: Eleventh rib of steers in first four groups.
Pigeonpea pasture only — Pigeonpea pasture with molasses
Grass pasture only — Grass pasture with molasses

Pen Feeding of Steers with Hawaiian Byproducts (Waialua Experiment)

This feeding experiment was carried on with the cooperation of Waialua Agricultural Company, Ltd., which furnished 24 steers sired by beef bulls but showing marked traces of dairy stock in their ancestry (figure 11). The steers were divided into 4 lots of 6 each. Three of the lots were pen fed on varying proportions of cane molasses and pineapple bran with soybean oil cake meal as the protein supplement and small quantities of green roughage (largely cane tops). The fourth lot was pastured in an 18-acre field of koa haole and fed supplementary cane molasses in an open trough.

The test started July 3 and continued 142 days to November 21, 1936, inclusive. A rain gauge in the koa haole pasture showed that

11.25 inches fell during the time of the experiment but two-thirds of the total rain fell in the month of October and the koa haole growth was retarded during the first three months due to lack of sufficient moisture.

The details of the rations, gains, and costs are shown in tables 18 and 19.

Figure 11.—Steers in dry-lot paddocks at start of Waialua experiment.

Table 18.—Plan and results of Waialua experiment

Lot No.	Steers in lot	Ration—			Average initial weight	Average final weight	Average gain per steer per day
		Pineapple bran	Cane molasses	Soybean oil cake meal			
		Percent	Percent	Percent	Pounds	Pounds	Pounds
I	6	50	30	20	650.8	909.5	1.82
II	6	40	40	20	654.7	932.9	1.96
III	6	30	50	20	655.0	873.3	1.54
IV	6	Koa haole pasture and molasses			666.9	828.3	1.14

Table 19.—Feed consumption, cost and value of beef produced

Lot No.	Feed consumed per steer per day		Feed consumed per pound gain		Feed cost per pound gain	Price received per pound dressed weight	Value of average carcass
	Concentrate	Green roughage	Concentrate	Green roughage			
	Pounds	Pounds	Pounds	Pounds	Cents	Cents	Dollars
I	20.8	10.0	11.4	5.5	11.0	15.85	81.13
II	20.8	10.0	10.6	5.1	9.8	16.06	82.46
III	20.6	10.0	13.4	6.5	11.7	15.96	78.57
IV	5.07[1]	pasture	4.46[1]	pasture	1.1[1]	15.47	71.48

[1] Molasses only.

Gains were materially better and feed consumption per pound of gain was much lower during the first 70 days of the test. The three pen-fed lots, I, II, and III, averaged 2.37 pounds daily gain and required only 7.7 pounds of the concentrate mixtures to make a pound of gain during the first 70 days; during the entire 142-day period the average daily gain of the steers in these three lots was 1.77 pounds and 11.8 pounds of the concentrate mixture were required for a pound of gain. This suggests that a better profit would have been made if the steers had been marketed sooner, although in such a case the steers might have brought a lower price per pound.

Based on the percentage of molasses contained in the mixtures, steers in lot I consumed 6.24 pounds; in lot II, 8.32 pounds; and in lot III, 10.3 pounds of cane molasses per steer per day. The feces were soft but the steers appeared to be in good health in all three lots.

If the value of koa haole pasture is assumed to be $2 per steer per month and cane molasses $5 per ton, the total feed cost of gains in lot IV was 6.9 cents per pound, which is materially lower than the cost of gains in the pen-fed lots. This would suggest that feeding supplementary cane molasses to steers on pasture is more profitable than pen feeding, or if pen feeding is practiced perhaps it should be limited to a shorter period. (Henke, Work, Burt)

SWINE

The swine herd, at the close of the fiscal year, consisted of 6 Berkshire and 10 Tamworth breeding animals, 27 younger purebred pigs, and 13 crossbred animals, used for research and instructional work. A heavy demand for breeding animals continues from swine raisers throughout the Territory; 12 purebred breeding swine were supplied to farmers during the year.

Home-Produced Ration for Fattening Swine

Hawaii is far removed from the source of the usual hog feeds, and such feeds are costly and sometimes hard to secure. A test was conducted to determine the effectiveness of a ration wholly locally produced as compared with another standard ration, 68 percent of the component parts of which were imported. The observation test

was conducted with 6 pigs having an average initial weight of 38.5 pounds and continued for a period of 80 days to February 10, 1937. The home-produced ration consisted of 53 percent sweetpotatoes, 20 percent cane molasses, 13 percent pineapple bran, 13 percent fish meal, and 1 percent salt, and cost $17.02 per ton. The control ration consisted of 68 percent barley, 20 percent cane molasses, 10 percent fish meal, 1 percent bone meal, and 1 percent salt, and cost $35 per ton. The home-produced ration was cooked before feeding as previous experiments did not show raw potatoes to have a high feeding value.

The pigs on the home-produced ration were fed all they would eat but the pigs on the control ration were limited in their feed intake so that their gains would not exceed those of the pigs on the home-produced ration. If given a full feed, the pigs on the control ration would have made far better gains, as has been demonstrated in numerous previous experiments. Based on feed required to make one pound of gain, the home-grown ration was worth 60 percent as much as the barley ration. The condensed results are shown in table 20.

Table 20.—Gains, feed consumed, and cost of gains in swine feeding test.

	Home-grown ration	Control ration
Final average weight (pounds)	104.70	103.30
Initial average weight (pounds)	38.80	38.20
Average daily gain per pig (pounds)	0.82	0.81
Average quantity of ration consumed daily per pig (pounds)	4.50	2.71
Ration required per pound of gain (pounds)	5.49	3.34
Feed cost per pound of gain[1] (cents)	4.60	5.84

[1] Does not include cost of cooking the home-produced ration or the cost of the pound of green roughage supplied to each pig.

While some economy in cost of gains resulted from the home-produced ration, gains were rather low. Sweetpotatoes at the time of this test cost $16 per ton, and barley cost $43 per ton. This was a student project and the pigs had not reached market weight when the test was discontinued. Further trials are contemplated to study economy of gains when both rations are full fed to market weight. (Work, Maneki[1])

[1] Senior student.

ALGAROBA BEAN MEAL AND PINEAPPLE BRAN AS MAJOR CONSTITUENTS OF RATIONS FOR FATTENING SWINE

In these tests, rations in which algaroba bean meal and pineapple bran (finely ground) each constituted well over half of the respective rations were compared with the standard control ration to note rapidity and economy of gains. These rations are given in table 21.

Table 21.—Experimental rations for fattening swine

	Control ration	Pineapple bran ration	Algaroba meal ration
Barley (percent)	68.0		
Pineapple bran (percent)		61.6	
Algaroba bean meal (percent)			70.5
Cane molasses (percent)	20.0	12.4	14.1
Fish meal (percent)	5.0	12.4	7.0
Soybean oil cake meal (percent)	5.0	12.4	7.0
Bone meal (percent)	1.0	0.6	0.7
Salt (percent)	1.0	0.6	0.7
Cost per 100 pounds (dollars)	1.82	1.11	1.26

Pigs from two litters born the same day were divided into three lots and the above feed mixtures were supplied in self feeders to the respective lots. A pound of green alfalfa was also given to each pig daily. The results of this test are shown in table 22.

Table 22.—Swine fattening trials

	Feed		
	Lot I Pineapple bran	Lot II Algaroba meal	Lot III Control
Pigs in lot	5	5	4
Average final weight (pounds)	184.4	191.9	194.2
Average initial weight (pounds)	60.8	60.6	68.0
Average total gain (pounds)	123.6	131.3	126.2
Days required to reach market weight	107	100	79
Average daily gain (pounds)	1.15	1.31	1.59
Average daily feed consumption—			
Concentrates (pounds)	5.92	7.38	7.70
Green alfalfa (pounds)	1.00	1.00	1.00
Concentrates consumed per pound of gain (pounds)	5.12	5.62	4.82
Total feed cost per pound gain (cents)	6.4	7.3	10.0

This trial indicates that from the standpoint of daily gains and quantity of feed required per pound of gain, the control ration was superior. However, feed costs of gains with algaroba meal were only 73 percent, and with the pineapple bran ration only 64 percent as much as when the control ration was fed. (Work)

DIGESTIBILITY OF HAWAIIAN FEEDING STUFFS

This work is being conducted in a special building erected for the purpose, in which each stall can be adjusted to fit the individual animal by means of movable mangers and floors above the stationary cement floor. Eight steers (4 Holstein and 4 Hereford) of around 650 pounds live weight are being used in the trials. On certain feeds, rabbits are also being used as a check against the steers in determining digestibility. These experiments have attracted much attention, as evidenced by the number of visitors and the widespread interest in the value of Hawaiian feeding stuffs.

As a general rule, each determination of digestibility is made on the basis of a 10-day preliminary period of constant feed intake followed by 2 consecutive 10-day collection periods. It is recognized that the value of any coefficients thus obtained depends upon the plane of nutrition. In order to establish such figures on local feeding stuffs, the feed intakes were adjusted so that the experimental animals made slight gains in weight. In this manner, the plane of nutrition was estimated to be approximately one and one-half times maintenance. While this level is, no doubt, less than under practical conditions, it seemed to be as close to such as it was possible to attain and still successfully carry out the various trials to their terminations.

Though the nutritive values of Hawaiian feeds are thus being determined with one species of ruminant, the results are directly applicable without material error to other ruminants. Morrison[1] has also applied such values in horse and swine feeding, particularly in the case of concentrates.

During the year just completed, the forage crops have been considered of first importance in view of the fact that little is known of the nutritive properties of many roughages used for stock feeding in Hawaii. Emphasis has been laid on the point that each grass deemed worthy of introduction on the range lands should have something of its nutritive value and palatability known before definite recommendations are made as to its widespread use.

Table 23 gives a summary of the results obtained in this work during the past year.

[1] Morrison, F. B. *Feeds and Feeding*, 1936, Morrison Publishing Co., Ithaca, N. Y.: 20th ed. rev.

Feeds tested	Dry matter	Crude protein	Nitrogen-free extract	Crude fiber	Ether extract	Ash	Total nutrients
	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Green Napier[1] (*Pennisetum purpureum*)—full growth							
Composition	35.64	1.57	14.16	14.43	0.59	4.90	
Coefficient of digestibility		60.00	74.00	79.00	74.00		
Digestible nutrients		0.95	10.40	11.40	0.43		23.71
Green Rhodes grass (*Chloris gayana*)—full growth							
Composition	28.83	2.32	11.42	10.73	0.57	3.79	
Coefficient of digestibility		58.00	60.00	70.00	50.00		
Digestible nutrients		1.35	6.85	7.51	0.28		16.34
Algaroba bean meal (*Prosopis chilensis*)—dried							
Composition	89.22	8.51	51.64	20.73	1.37	3.82	
Coefficient of digestibility		70.00	70.00	54.00	75.00		
Digestible nutrients		5.96	36.15	11.19	1.04		55.62
Cane bagasse—sifted							
Composition	90.34	1.75	39.92	40.64	0.87	7.16	
Coefficient of digestibility		Negative	41.00	58.00	53.00		
Digestible nutrients		.....	16.37	23.57	0.46		40.98

[1] One 10-day trial.

Table 23.—Analyses of digestion coefficients and digestible nutrients of some Hawaiian feeding stuffs

Feeds tested	Dry matter	Crude protein	Nitrogen-free extract	Crude fiber	Ether extract	Ash	Total nutrients
	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Green alfalfa—half bloom							
Composition	19.88	4.06	7.81	5.42	0.78	1.81	
Coefficient of digestibility		74.00	73.00	46.00	36.00		
Digestible nutrients		3.00	5.70	2.49	0.28		11.82
Green Panicum grass (*Panicum purpurascens*)—full growth, no seed heads							
Composition	25.57	2.06	11.07	8.75	0.47	3.21	
Coefficient of digestibility		60.00	64.00	67.00	52.00		
Digestible nutrients		1.24	7.08	5.86	0.25		14.74
Green koa haole tops (*Leucaena glauca*)—stems, leaves, seeds in pods							
Composition	30.71	7.44	12.37	7.44	0.83	2.73	
Coefficient of digestibility		65.00	74.00	35.00	36.00		
Digestible nutrients		4.84	9.15	2.60	0.30		17.26
Green pigeonpea tops (*Cajanus cajan*)—top one-third of plant including pods							
Composition	49.66	9.41	20.07	14.74	2.61	2.82	
Coefficient of digestibility		69.00	78.00	50.00	69.00		
Digestible nutrients		6.49	15.65	7.37	1.80		33.57

Table 23.—Analyses of digestion coefficients and digestible nutrients of some Hawaiian feeding stuffs (Continued)

Tests with rabbits have been made with two single feeding stuffs—Rhodes grass and algaroba bean meal—and with two complete dairy rations, in order to determine whether results obtained with these animals are of the same order as those obtained with steers. The results of the trials are not available at this time.

To strengthen the value of dairy animal- and pig-feeding trials, the digestibility of rations for cows and pigs is also being tested. The values of two dairy rations have already been determined in addition to the feeds in table 23. The results obtained in such tests will be included in the final reports on the respective feeding trials and will aid in interpreting previously acquired data. (Work)

POULTRY HUSBANDRY

POULTRY RATIONS

FRESHLY CUT ALFALFA AS COMPARED WITH FRESHLY CUT TREE KALE (*Chou moellier*) IN POULTRY RATIONS

Comparison of newly cut alfalfa and tree kale in poultry rations during a 4-year period indicated that the difference in the intensity of yolk pigment of the eggs was not statistically significant in favor of either group, nor was there any difference in the weight of eggs produced by each lot of hens. Normal body weight was maintained in each group with no appreciable difference in gains. Tree kale appeared to be slightly superior to alfalfa as a green feed for the production of eggs. There was no significant difference in the weights of day-old chicks or in the number of dead germs; however, a slight increase in the percentage of fertile eggs was obtained from the hens which received newly cut kale. Tree kale was also superior to alfalfa in the percentage of strong chicks hatched. The total feed cost to produce a dozen eggs was practically the same in each group. There was no significant difference in the mortality, both groups having a lower mortality than normal for the Territory.

Table 24 shows the comparative value of fresh kale and fresh alfalfa. (Bice)

Table 24.—The comparative value of fresh-cut alfalfa and fresh-cut tree kale in egg and chick production

Supplement	Mean body weight after six months	Intensity of color of egg yolk	Mean weight per dozen of eggs	Average cost of feed per dozen of eggs	Weights of day-old chicks	Strong chicks hatched	Egg production
	Pounds		Ounces	Cents	Grams	Percent	Percent
Alfalfa	3.52±0.51[1]	1.715±0.338	23.182±1.880	15	36.668±2.527	62.25	58.30
Tree kale	3.66±0.450	1.730±0.370	22.817±1.547	13	37.747±2.426	68.91	64.44

[1] Standard error.

Poi, Taro, and Taro Waste in Fattening Rations for Poultry

Three fattening trials were made during the past year, using poi and taro waste to replace high-priced corn meal in a proved fattening ration. These trials were conducted with purebred Single Comb White Leghorn, crossbred Single Comb White Leghorn, purebred Rhode Island Red, and crossbred Rhode Island Red broilers. With purebred Leghorns fed on a standard wheat middling and corn meal ration, the cost per pound of gain in live weight was 27 cents. Using a ration substituting 40 percent of taro waste for corn meal, the cost per pound of gain was 17 cents. Purebred and crossbred lots were fattened at 15 to 22 cents per pound using the taro ration. With broilers selling at 25 cents to 45 cents a pound live weight on the Honolulu market, it is possible to show a profit by feeding these local feeds. In the 40-percent taro-waste groups, the feed cost per pound of gain varied from 15 to 25 cents, and in the 40-percent poi groups from 22 to 24 cents. These figures indicate economical production of quality poultry meat. (Bice)

Cane Molasses in Fattening and Laying Rations

Cane molasses is a cheap carbohydrate feed in Hawaii, and its use in fattening and laying rations for poultry has been under investigation. A standard ration containing 40 percent wheat middling and 60 percent corn meal, and costing $2.29 per hundred pounds, was modified to form three levels of molasses intake by substituting 3, 5, and 7 percent of molasses. With corn meal at $49 per ton and molasses at about $5 per ton, substitution of molasses resulted in considerable saving.

With purebred males fed a 5-percent molasses ration, the cost per pound of gain was 18 cents, compared with 19 cents for crossbred cockerels on the checks and 20 cents on the 5-percent molasses rations.

In the female lots, the purebreds fed a check ration put on weight at 20 cents per pound, compared with a cost of 21 cents for crossbred females fed 5 percent cane molasses. However, the crossbred females in the 5-percent molasses lot had a cost per pound of gain of 21 cents as compared with 30 cents in the purebred lots on the same ration.

These fattening trials indicated a lower dressing loss in the crossbred groups as compared with the purebred group.

In the laying phase of this study, four lots of Single Comb White Leghorn pullets completed 9 months of lay. The birds in each lot appeared to be in good physical condition. Egg production was based on the original number of birds in each lot. Feed consumption, feed costs, and returns above feed costs were based on living hens. Table 25 summarizes the data obtained over the 9-month period.

Table 25.—Data from tests in which varying amounts of cane molasses were added to laying mash

Molasses in feed	No. of birds on test at start	Average egg production per hen	Average weight per hen at end of experiment	Mortality	Total feed consumption per hen	Average feed cost per hen	Wholesale value of eggs per hen	Return above feed cost per hen
Percent			Pounds	Percent	Pounds	Dollars	Dollars	Dollars
0 (check)	64	160.7	4.00	6.56	61.9	2.81	4.54	1.73
3	54	162.3	4.25	6.15	62.2	2.65	5.23	2.58
5	62	134.8	4.05	18.27	58.7	2.51	4.32	1.81
7	88	143.3	4.02	18.35	61.5	2.47	4.57	2.10

Data presented in table 25 show that the 3-percent molasses group had the highest egg production per hen, the lowest mortality, the highest wholesale value of eggs, and the best returns above feed cost per hen. As molasses is a byproduct of the sugarcane industry, it is an economical feed and can be incorporated in small amounts in poultry rations, thus reducing the cost of mash feeds. (Bice, Tower)

ALL-STEEL POULTRY HOUSES

Three all-steel poultry houses, two of which are 14 feet by 24 feet and one 8 feet by 9 feet, were constructed for further study on houses applicable to conditions found on the average poultry farm in the Territory. Hawaii, on account of disease, insects, parasites, and climate conditions, requires somewhat different housing

conditions than those of the mainland. The construction of one of the larger all-steel houses is shown in figure 12. The small house, with a capacity of 25 hens, rests upon a concrete floor around which is a moat serving as a guard against crawling insects. This house has been in service for 7 months and has proved to be highly desirable under all prevailing conditions. Temperature readings taken during the day at 2-hour intervals show that this all-steel house is just as cool as a wooden type of house covered with 3-ply roofing paper. In the preliminary trial, in which the smaller type of house was used, production and mortality records were normal.

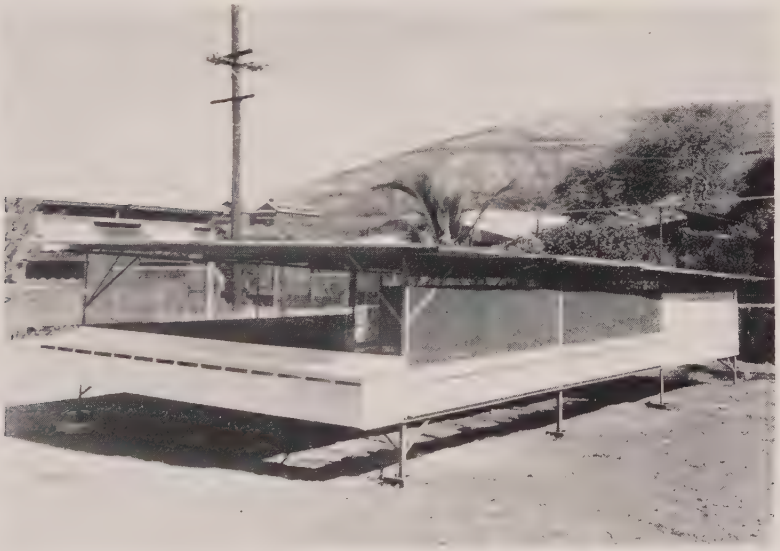


Figure 12.—View of 14-foot by 24-foot all-steel poultry house. Note legs set in concrete blocks.

On the basis of this trial the larger units were constructed; however, the concrete floor and moat were eliminated because of costs. The legs of the 14-foot by 24-foot house rest in concrete blocks in each of which a 2-inch recess, filled with oil, prevents crawling insects from entering the house. Records are being kept at present to determine the efficiency of this house under prevailing conditions. (Bice, Botelho)

BATTERIES FOR LAYING AND BREEDING HENS

In continuation of an investigation to determine the efficiency of hen batteries for laying and breeding stock in Hawaii, 60 Single Comb White Leghorn pullets have been confined in a 60-hen commercial type laying battery since December 1, 1936. Data gathered over a period of 6 months indicate that the mortality has been 12 percent, due primarily to range paralysis. The hens were fed commercial egg mash and scratch feed containing 1 percent of refined cod-liver oil. It cost $1.36 to feed each hen for the 6 months of the experiment. An average production of 132.29 eggs per hen was obtained, based on the original number of birds in the study. These eggs had a wholesale value of $4.17, leaving a profit of $2.81 per hen above feed costs. Eggs produced over a period of 6 months averaged 22.75 ounces per dozen, were of good shell texture, and rated high in interior quality. A gain in body weight of 0.35 pound tends to indicate that close confinement in laying batteries did not have a detrimental effect upon the physical condition of the pullet in its first 6 months of lay. These results indicate that the use of batteries compares favorably in cost and efficiency with pen methods. (Bice)

ARTIFICIAL ILLUMINATION FOR LAYING HENS

This project, which had been in progress for 5 years, terminated April 30, 1937, and the data presented herewith are averages for the period. Detailed results have been published.[1] Five trials were conducted during this time, with new groups of birds being selected annually.

Beginning October 1, lights were turned on for use throughout the shorter days of the year. They were at first turned on at 5 a.m., but the lighting hour was 15 minutes earlier each subsequent week until the lights were coming on at 4 a.m. They remained at this lighting hour until March 1. Beginning March 1, the lighting hour was 15 minutes later each week until the length of day was 13 daylight hours.

As a result of lengthened day, the birds consumed more feed, maintained normal body weight, and partial molt was reduced. A summary of data accumulated at Honolulu's latitude of 21.5°

[1] Hawaii Agr. Expt. Sta. Circ. 12.

North shows that artificial illumination was responsible for a decided increase in egg production during the months of December, January, and February when egg prices were at their peak, with increased earnings per hen.

Results from the 5-year period indicated that artificial illumination was an efficient and economical means of increasing the yearly earning power of pullets in their first year of lay. The tests showed that it cost 20 cents to feed a pullet per month, and that each pullet consumed approximately 8 pounds of feed during the period. On a dozen egg basis it cost 3 cents less to produce eggs from the pullets receiving artificial illumination than from those not illuminated. (Bice)

CROSSBREEDING FOR MEAT AND EGG PRODUCTION

Five matings using Japanese Shamo Game males mated with Barred Plymouth Rock, Rhode Island Red, White Leghorn, Black Australorp, and Shamo Game females were studied for meat and egg production. In the preliminary laying phase of this study, pullets from the above matings were trapnested for 4 months. Results indicate that a satisfactory egg production is possible from crossbred pullets. Several pullets averaged 20 to 26 eggs per month, and the average production per pullet over a 4-month period compared favorably with purebred pullets of the same variety as the female parent. Two hundred crossbred pullets are now being trapped for an entire year; thus more accurate records will be available at the completion of the test than are now available from the 4 months' preliminary trial.

Approximately 2,500 crossbred chicks were hatched during the time of the experiment. Groups of chicks were fattened at various periods according to broiler, fryer, and roaster classification. The White Leghorn female and Japanese Shamo Game male cross produced the best broilers. All matings produced good fryers. The Barred Plymouth Rock and Rhode Island Red females mated with the Japanese Shamo Game male produced the best roasters. A manuscript on this project is being prepared which gives in detail the results of this study. (Bice, Tower)

PARASITOLOGY

STUDIES ON LIVER FLUKES OF CATTLE

The Occurrence of Liver Fluke (*Fasciola gigantica*) in Hawaii

Liver flukes (*Fasciola gigantica*) (figure 13) were found in Hawaii as early as 1892. In that year and in 1894, flukes from a horse and a sheep, respectively, from Honolulu, were collected by G. R. Rowat and submitted to the Bureau of Animal Industry, U. S. Department of Agriculture. Although at that time they were diagnosed as *Fasciola hepatica*, a recent re-examination by A. McIntosh of that Bureau found them to be *Fasciola gigantica*. Lutz, in 1892, found liver flukes present in cattle on the Islands of Kauai, Oahu, Maui, and Molokai.

In respect to the possible source of importation of *Fasciola gigantica* into the Territory, this species of fluke is known to occur in Africa, Assam, Ceylon, China, Egypt, Formosa, India, Indo-China, Kenya, Northern and Southern Rhodesia, Nederlandsch-Indie, the Philippines, Spain, and Tanganyika Territory. Of the local animals which were imported from or near any of these localities previous to 1890 were the following: Water buffaloes from China about 1880; horses from Arabia and India in 1884; a deer from eastern Siberia in 1856, and eight others from Japan in 1867. Other livestock imported previous to 1890 from areas not known to have this species of fluke were as follow: Cattle from continental United States, Holland, Australia, New Zealand, and the British Isles; sheep from continental United States, Australia, Germany, and France; goats, swine, and horses from the continental United States.

There is also a possibility that the flukes were introduced into the Territory in the encysted stage, attached to various sorts of vegetation imported from endemic areas and eaten by local animals. (Alicata)

Life History of *Fasciola gigantica*

In last year's annual report of the station (p. 86), under the title "The Life History of the Liver Fluke, *Fasciola hepatica*," the species of the parasite was erroneously given as *Fasciola hepatica*. *Fasciola gigantica* is the only species which thus far is known to occur in cattle on the Islands of Kauai, Oahu, Maui, Molokai, and

Hawaii. During the past year, additional data have been secured relative to the development of the fluke in the snail, *Fossaria ollula,* and in the final host. The snail, *Fossaria ollula,* which was then reported from Oahu, has now been found to occur on all the islands where flukes are known to exist. The various stages in the development of the fluke are given below.

Figure 13.—a. *Fasciola gigantica* from liver of cattle in Hawaii; b. freshwater snails, *Fossaria ollula* (snails slightly enlarged).

Egg. The eggs which are deposited with the feces of infested animals are about 0.156 to 0.197 millimeter long by 0.09 to 0.10 millimeter wide and are larger than those of *Fasciola hepatica,* which are approximately 0.12 to 0.134 millimeter long and 0.07 to 0.074 millimeter wide. At a temperature of about 78° to 82° F. the eggs develop, and the miracidia escape from the shell in 14 days.

Miracidium. The miracidia are about 0.16 to 0.19 millimeter long by 0.04 to 0.05 millimeter wide, and swim actively in water in search of snails. If no snails are accessible, they have been found to die within a period of 12 to 24 hours at a temperature ranging from 72° to 82° F.

The miracidia are not killed readily in the solution of 1:500,000 copper sulphate commonly used to kill fresh-water snails. In dilu-

tions of 1:1,000, 1:4,000, 1:8,000, and 1:32,000, they died after 6, 8, 15, 30 minutes, and 4 hours respectively. In dilutions of 1:120,000 they were found alive after 6 hours.

Brackish water may be lethal to miracidia. They have been found to die in 50-percent and 25-percent dilutions of sea water in 1 and 20 minutes, respectively; in 10-percent sea water they were still alive after 5 hours.

Sporocyst. Several miracidia may attack one snail; soon after entering the snail, each miracidium transforms into a sporocyst. The germ cells in the sporocyst develop into rediae which, after about 5 days, leave the sporocyst but remain in the snail.

Redia. The rediae grow within the snail and may reach 2 millimeters in length. The rediae give rise to a generation of daughter rediae, and these in turn give rise to cercariae.

Cercaria. The cercariae, after reaching full development, come out of the daughter rediae and eventually escape from the snail. Under experimental conditions at a temperature of 76° to 80° F., the cercariae were liberated from snails on the thirty-ninth day following infestation. The cercariae have bodies about 0.32 to 0.38 millimeter long and tails about 0.8 millimeter long. They are very active in water, but usually encyst on vegetation near the water level within a period of about one-half hour. Cercariae fed to guinea pigs have not produced an infection.

Metacercaria. The cercariae which eventually encyst and drop their tails are known as metacercariae. The cyst surrounding the metacercaria is made up of two hard layers, more or less circular. The outer cyst is about 0.23 to 0.26 millimeter in diameter and is, therefore, larger than that of *Fasciola hepatica,* which is about 0.18 to 0.20 millimeter in diameter.

Metacercariae encysted for 1 hour have not produced an infection when fed to guinea pigs; however, infection took place from those which had encysted for 5 hours. Encysted metacercariae have been found alive after 20 days' drying at a temperature of about 80° F., but were found dead after a 30-day period. They withstood dry heat of 80° C. and 60° C. for 1 and 5 minutes respectively, but were killed when subjected to temperatures of 80° C. and 70° C. for 3 and 5 minutes respectively.

Development of the Adult. Encysted metacercariae have been fed to guinea pigs, rabbits, and a calf. Immature liver flukes 6 to 8 millimeters long have been found in guinea pigs 40 days after experimental infection. When cysts were fed to rabbits, fluke eggs were found in the feces of these animals 77 to 84 days later. Postmortems of rabbits 81 to 87 days following infection revealed adult flukes 26 to 32 millimeters long and 6 to 9 millimeters wide. A calf which was fed fluke cysts showed fluke eggs in the feces after 84 days. Three mature flukes, 37 to 42 millimeters long and 11 millimeters wide, were recovered at postmortem of this animal 216 days following infection. (Alicata)

Experimental Feeding of Liver Fluke Cysts to a Horse and a Mule

On December 28 and February 5, 1936, a horse was fed about 350 and 300 liver fluke cysts, respectively. The horse was killed on April 25, 1936, and no flukes or liver lesions were found.

Beginning on September 11, 1936, a mule was fed at intervals during a period of 13 days a total of 2,300 fluke cysts. The animal was killed on December 17 and no fluke infection was found.

In the above experiments, the vitality of the cysts was checked by feeding to guinea pigs cysts from the same lot that were fed to the experimental animals; infection took place in the guinea pigs.

In addition to the above experiments, postmortem examinations of 5 horses from various liver fluke endemic areas have revealed no presence of liver flukes.

In spite of the foregoing negative results, local veterinarians on the Island of Kauai have reported finding liver flukes in horses during the year 1917; in addition, G. R. Rowat in 1894 collected liver flukes said to be from a horse in Honolulu. (Alicata, Swanson)

Experiments on Active Immunity to Liver Flukes in Rabbits and a Calf

According to Kerr and Petkovich,[1] rabbits subjected to a series of intraperitoneal injections of 1 cubic centimeter of 1-percent suspension of dried powdered fluke material (*Fasciola hepatica*) in physiological saline solution, acquired some resistance to fluke infection. The flukes that developed were said to remain immature and in some cases to become calcified.

[1] *Journal of Parasitology*, V. 21(4) 1935.

Experiments conducted in this laboratory using *Fasciola gigantica* did not confirm the above observations. A series of 7 rabbits and 1 calf was used; 3 additional rabbits served as controls. (Alicata)

LIVER FLUKE CONTROL

Methods of Control

Effective control of flukes on eight ranches and dairies was accomplished by the following methods:

Drainage. On 5 ranches, 32,010 linear feet of ditches, 3 feet wide and 3 feet deep, were dug to drain low wet areas. The cost of ditching was less than 10 cents per linear foot.

Fencing. On 5 premises, 37,234 feet of fences were built to prevent cattle from grazing in low, wet areas. The cost of such fencing per linear foot was not more than 2.5 cents.

Copper Sulphate. On 2 ranches, 4,321 pounds of this chemical were used in a dilution of 1 part to 200,000 parts of water to eradicate snails in ditches. This dilution proved to be effective. Previous preliminary experiments with copper sulphate on other ranches proved that 1:500,000 dilution was not effective in killing snails due to the amount of organic matter and vegetation in Hawaiian streams. (Swanson)

Manure Disposal and Care of Water Troughs

Washings containing feces of liver fluke infested cows from the milking barn into pastures where snails are abundant have been found to be a method of infecting snails. On one ranch, nearly all snails collected in such a pasture were releasing considerable numbers of cercariae, and as a result the entire herd was heavily infested. This was corrected by fencing in the area into which the manure and water drain. On another dairy farm where the infested manure was used for the purpose of fertilizing a wet pasture area, nearly every animal was infested. Since draining the area, the manure is being used without any danger.

On several dairy farms, snails with cercariae were found in the vicinity of and sometimes in low, leaky, wooden water troughs. These troughs were either repaired or abandoned and replaced by concrete troughs with automatic floats. (Goo)

Fire Torch

In a paddock and pasture where snails infested with liver fluke cercariae were abundant, a burner which works on the same principle as a plumber's blow torch was used in killing the snails, snail eggs, and liver fluke larvae encysted on the grass. This burner uses a gallon of kerosene an hour and produces a powerful, reddish-blue flame 3 inches in diameter and 30 inches long. The size of the flame is easily controlled by a regulating valve. This method of snail control is simple and inexpensive, and should have a wide application especially in small areas within pastures and paddocks, and along the banks of streams containing snails. (Goo)

Economic Losses Due to Flukes

On one ranch, a fine lowland pasture area of 100 acres of *Panicum* grass could not be used because liver fluke cysts were prevalent. The remainder of the ranch was dry and hilly and the feed available was insufficient. This made it necessary for the ranch to purchase roughage for a milking herd of 350 cows, but if the *Panicum* field had been safe to use, the cost of feeding this herd would have been considerably reduced.

An instance of a swamp in a highly infestuous condition was shown when one fluke-free cow, recently shipped in from the mainland, had access to the grass on the edge of the swamp. This cow was imported on February 25, 1937, and in June her milk production dropped from 16 pounds to 5 pounds per milking during a period of 2 weeks. She was slaughtered and 492 flukes were counted. (Goo)

Drug Experiments

(1) Carbon tetrachloride, when administered in 10-cubic centimeter dosages followed 3 to 4 hours later with magnesium sulphate, was fatal to 2 lactating Holstein cows 8 to 10 years of age. A 5-cubic centimeter dosage, either followed or not by magnesium or sodium sulphate, to each of 9 nonlactating Holstein and Guernsey animals and 2 Aberdeen Angus steers ranging in age from 1 to 3 years did not prove injurious to the health of the animal nor effective in destroying flukes in the liver, as postmortem and examination of feces for ova disclosed.

(2) *n*-Butyl chloride in dosages of 250 to 350 cubic centimeters was administered to 3 Holstein cows. It was not effective in destroying the flukes.

(3) *p*-Tertiary-butylphenol was not effective in destroying the flukes. The dosage per cow was 20 grams. Either magnesium or sodium sulphate was given as a purgative several hours after administration.

(4) Distol, a proprietary drug in the form of capsules, each capsule containing 1 gram of aspidinolfilicic acid, 10 grams of hexachloroethane, and 1.6 grams of talc, is recommended as being effective in destroying liver flukes in cattle. The dosage prescribed for each cow is based on 3 capsules for the initial 200 pounds live weight and 1 capsule for each 75 pounds additional weight. It is given on 2 consecutive days—one-half the dosage on each day. Feed is withheld from the cattle for 12 hours before and 3 hours after each treatment.

(a) In order to determine the effect of Distol on lactating cows, four cows were selected for tests. After one-half the prescribed dosage was administered, the cows were dull and weak and were continually lying down without any inclination to feed. The feces were dark and loose. The second half of the dosage was not given. The second day after treatment, one cow died; a necropsy of this animal revealed 5 adult liver flukes in the liver, of which only 1 was dead. The milk production of the remaining 3 cows dropped an average of 6 pounds per cow daily. Two cows recovered the milk losses 4 weeks after the treatment; the other cow was fairly advanced in lactation and was dry 2 months later. The flavor of the milk was slightly salty for two days. Fecal examination for fluke ova 2 months later showed 2 cows to be fluky and 1 cow free from flukes.

(b) To determine the effect of the drug on dry cows within 2 months of parturition one Holstein cow, No. 109, was treated with one-half the prescribed dosage while another Holstein cow, No. 142, which had aborted the previous year, was given the full dosage; no deleterious effects on the animals were noted. Cow 142 produced a normal calf 17 days later, and cow 109 also dropped a normal calf 2 months after the treatment. Cow 109 produced the same quantity of milk at freshening as during previous freshening

periods. Cow 142 produced 42 pounds of milk daily, which was more than her previous year's production. Examination for fluke ova in feces of cow 142 about a month after treatment revealed no fluke ova. Cow 109, which was treated with only one-half the prescribed dosage, remains fluky.

(c) The use of Distol in unbred heifers does not appear to have any deleterious effects on the animals. This observation was based on the feeding of full dosages of 11 and 7 capsules, respectively, to a Holstein and a Guernsey heifer of about 16 months of age.

(d) To test the efficacy of the drug in the destruction of the flukes in the liver, two Aberdeen Angus steers were treated with Distol and slaughtered 70 hours after treatment. Results are shown in table 26.

Table 26.—Efficacy of Distol treatment of two Aberdeen Angus steers

			Flukes at autopsy		
Age	Weight	Dosage	Alive	Dead	Efficacy
Years	Pounds	Capsules			Percent
3	1,100	15	4	115	96.6
3	1,025	14	0	74	100.0

The above tests show Distol to be highly efficacious in the destruction of flukes in the livers of nonlactating cattle. Work has been planned to secure further data on the use of Distol with dairy cattle. (Swanson, Goo)

STUDIES ON POULTRY PARASITES

Parasites of Chickens in Hawaii

During the past year, several previously unreported parasites of poultry, together with new intermediate hosts, have been found. Table 27 lists the parasites and carriers which have been identified up to the present time. (Alicata)

Table 27.—Poultry parasites and carriers

Parasite	Location found	Intermediate host, if any, in Hawaii. The mark "*" indicates intermediate hosts found naturally infected; the others were found through experimental infection.
Roundworms:		
Oxyspirura mansoni	eye	Roach: *Pycnoscelus surinamensis*
Gongylonema ingluvicula	crop	(Unknown in Hawaii)
Dispharynx spiralis	proventriculus	Sow bug: **Porcellio laevis*
Tetrameres americana	do	Beetles: **Dendrophilus* sp., **Dermestes vulpinus*, **Epitragus diremptus*, and **Gonocephalus seriatum* Earwig: **Euborellia annulipes* Grasshopper: *Conocephalus saltator* Roach: **Blatella germanica* Sandhopper: **Orchestia platensis*
Cheilospirura hamulosa	gizzard	*Grasshoppers: *Conocephalus saltator, Atractomorpha ambigua, Oxya chinensis* Sandhopper: **Orchestia platensis* Beetles: *Carpophilus dimidiatus Dactylosternum abdominale, *Epitragus diremptus, Euxestus* sp., *Litargus balteutus, Palorus ratzeburgi, *Tenebroides nana, Tribolium casteneum, Typhaea stercoria* Weevils: *Oxydema fusiforme, Sitophilus oryzae*
Ascaridia galli	small intestine	(None)
Capillaria sp.	cecum	(Unknown in Hawaii)
Heterakis gallinae	do	(None)
Heterakis sp.	do	(None)
Strongyloides sp.	do	(None)
Tapeworms:		
Choanotaenia infundibulum	small intestine	Beetles: **Dermestes vulpinus*, **Epitragus diremptus*, **Gonocephalus seriatum*
Hymenolepis carioca	do	(Unknown in Hawaii)
Hymenolepis exigua	do	Sandhopper: **Orchestia platensis*
Raillietina cesticillus	do	Beetles: **Dermestes vulpinus*, **Gonocephalus seriatum*
Raillietina tetragona	do	(Unknown in Hawaii)
Flukes:		
Brachylaemus sp.	cloaca	(Unknown in Hawaii)
Protozoa:		
Coccidia (several sp.)	small intestine & cecum	(None)
Arthropods:		
Lice, mites, fleas	on body	(None)

CONTROL OF THE COCKROACH (*Pycnoscelus surinamensis*), THE CARRIER OF EYEWORMS OF POULTRY

The control of eyeworms depends a great deal on the control of the carrier. For controlling cockroaches, several experiments have been conducted involving the use of toads (*Bufo marinus*), butyric fermentation baits, carbon bisulphide, and oil spraying.

Toads, which are known insectivorous animals, have a fondness for large cockroaches. In one experiment during a period of 24 hours, when toads were placed in a fenced area containing many cockroaches, each was found, at necropsy, to have eaten from 11 to 25 roaches, plus a few beetles. On account of the limited number of roaches which toads can eat, they cannot be regarded as very efficient in the biological control of these insects, but, depending on the number used, they may be regarded as beneficial in reducing the cockroach population to a certain degree.

In cooperation with Donald Starr of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, butyric fermentation baits were in some cases found effective in capturing up to about 700 roaches in a single trap. Each trap consisted of a wide-mouthed glass jar about 9 inches high and 5 inches wide, which contained the bait. This trap was set in the ground so that the mouth opening of the jar was at a level with the surface of the ground.

Carbon bisulphide solution has been found effective in certain areas in controlling roaches. The chemical was allowed to escape in the ground through small openings which had been drilled in sunken pipes. In one experiment about 93 percent kill of roaches was obtained. Although this method of control is effective, the inflammability of the chemical makes its use limited in scope. There is a possibility that other noninflammable chemicals or gases may be used in areas where control of burying arthropods is required.

The use of Diesel oil on cockroach-infested ground has been found somewhat effective in destroying roaches. The procedure used consisted in first removing all poultry manure and top portion of the loose sandy soil which is commonly found in roach-infested areas. This was followed by a thorough spraying of the ground surface with Diesel oil. By this method many roaches have been

found dying during the process of spraying or within one or two days later. (Alicata)

STUDIES ON PARASITES OF SWINE

Parasites of Swine in Hawaii

The parasites which have thus far been collected from hogs in the Territory are listed in table 28.

Table 28.—Parasites of swine in the Territory

Parasite	Location found
Roundworms:	
Trichinella spiralis (larval stage)	Muscle
Choerostrongylus pudendotectus	Lungs
Metastrongylus elongatus	Do
Ascarops strongylina	Stomach
Hyostrongylus rubidus	Do
Ascaris suum	Small intestine
Strongyloides sp.	Do
Trichuris suis	Large intestine
Stephanurus dentatus	Kidney
Tapeworms:	
Taenia hydatigena ("Bladderworm")	Attached to mesentery and liver; they reach adulthood in dogs.
Lice:	
Haematopinus suis	Skin
Mites:	
Sarcoptes scabiei suis	Do

A brief survey of the occurrence of trichinae in hogs in the Territory has been made. Of 61 domesticated hogs and 41 wild hogs examined from the Island of Hawaii, 1 and 6, respectively, were found infested; in addition, of 2,130 rats and 70 mongooses (*Mungos birmanicus*) examined, 57 and 17, respectively, showed infestation. No trichinae were found in 92, 130, and 30 domesticated hogs examined from the Islands of Maui, Oahu, and Kauai, respectively. Of 1,904 rats and 22 mongooses examined on Maui, 1 and 2, respectively, were found infested. Of 352 and 601 rats examined from Oahu and Kauai, respectively, none showed infestation. (Alicata)

RODENT CONTROL

The rodent control laboratory, installed in the fall of 1935, has continued its operations with increased staff during the past fiscal year, with entire emphasis on rat abatement.

The work of the station has been conducted in close cooperation with the Bureau of Biological Survey, U. S. Department of Agriculture, and on July 1, 1936, H. G. Hansen of that Bureau became project leader for the combined Hawaii Experiment Station and Biological Survey program. He was succeeded by H. J. Spencer on July 1, 1937.

A memorandum of the Hawaiian Agricultural Advisory Committee provided that sugar processing funds for the rat abatement campaign be allocated as follows:

Honolulu administration and research		$22,250
Island of Maui		35,000
Island of Hawaii—		
Hamakua region	$37,750	
Kona region	15,000	52,750
TOTAL		$110,000

It was further provided that operations in the Hamakua region, Hawaii, and on Maui be in cooperation with the Territorial Board of Health and that the organization of that Board be used. The experiment station furnished the labor and materials, but the work was under the direct supervision of the Board of Health.

By October, 1936, it had become apparent that funds allocated for research activities in Honolulu should be increased and on October 29, the Hawaiian Agricultural Advisory Committee voted to transfer $5,000 from the Maui allotment and a like amount from the Hamakua allotment to the Honolulu fund. Shortly thereafter, the Hawaiian Sugar Planters' Association made a gift to the University of Hawaii of $10,000, to be spent for rodent control equally in the Maui and Hamakua regions. This step, in effect, restored the allotments for those districts. The non-Federal nature of these funds made it possible to purchase thallium sulphate of foreign origin for rat control at a price markedly below the price for domestic thallium.

Actual disbursements from the rat abatement funds and balances as of June 30, 1937, are shown in table 28 (pages 116-117).

LIFE HISTORY STUDIES OF RATS

The first step in the rat abatement program was a study of the life habits of the four species of rats known to inhabit the Territory

of Hawaii.[1] With this background knowledge, it was possible to determine the proper time to apply control measures, a factor as important to the final results as the effectiveness of the measures themselves.

Rat Populations

Through the combined efforts of the cooperating agencies in the rat abatement program from December, 1935, to the present fiscal year, the following rat population averages have been found (table 29).

Table 29.—Rat populations ascertained during abatement campaign

Region[2]	Average No. per acre	Terrain
Hamakua, Hawaii	40-60	Gulch areas
Kona, Hawaii	10-15	Coffee ranches
Maui	25-35	Gulch areas
Lanai	15-25	Pineapple fields
Oahu	25-50	Waste lands
Kauai	35-50	Sugarcane fields

Breeding Rate

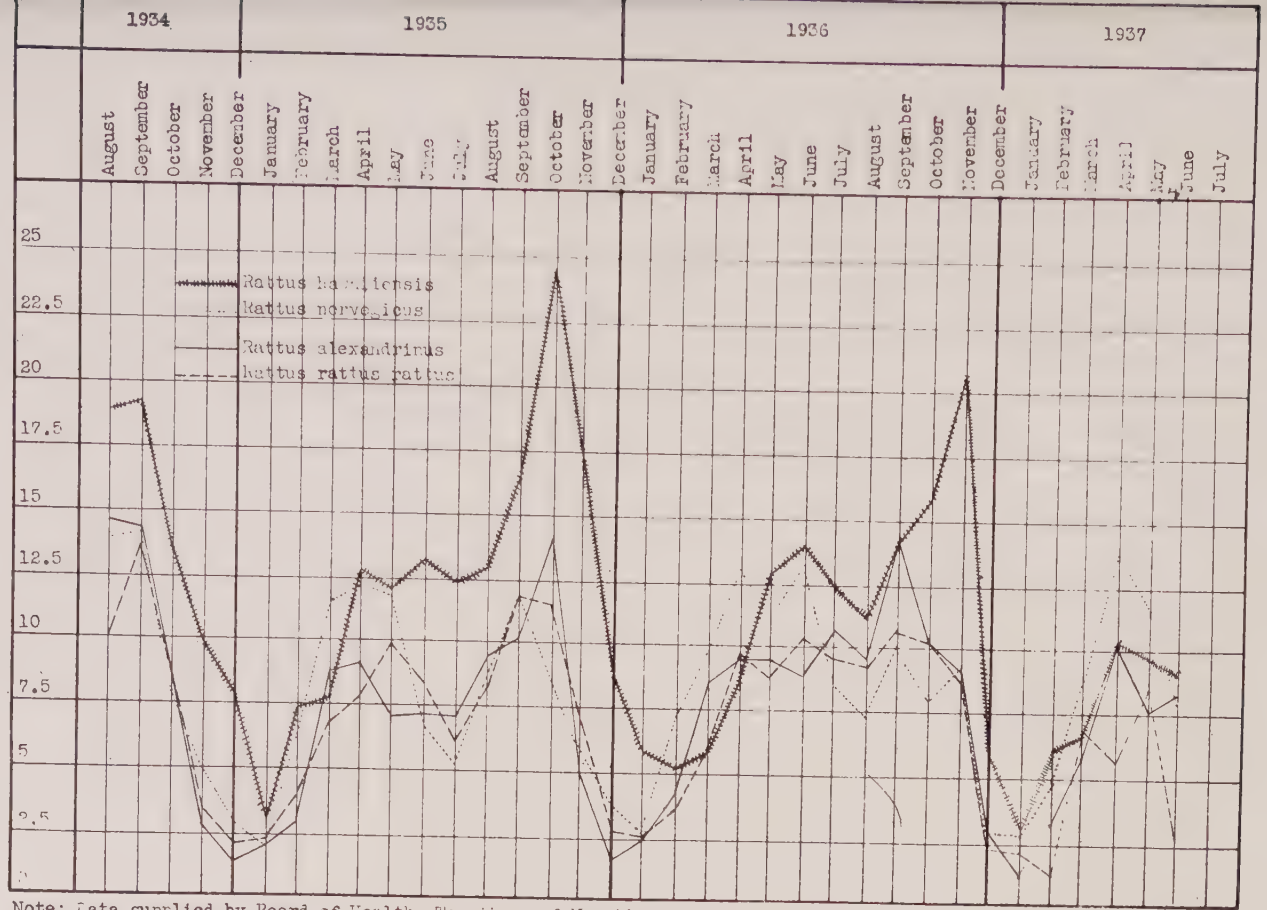
In Hawaii—the land of mild, even climate—rats have been found to give birth to young much more often than do similar species on the mainland United States. Here, pregnant rats have been recorded for each month of the year. A graph compiled from data furnished by the Board of Health dating back to August, 1934, and carried up to the present fiscal year gives a very clear picture of the breeding rate, by months, of the four species of rats inhabiting the Hamakua district of the Island of Hawaii. This is shown in figure 14, by courtesy of the Board of Health.

Summarizing data for the Territory, the average number of fetuses per pregnant female rat examined has been found to be:

Rattus norvegicus	6-8
Rattus rattus (black)	4-6
Rattus alexandrinus	4-6
Rattus hawaiiensis	3-4

[1] These species are described in the annual report of the station for 1936, page 90.

[2] These figures are derived from only those areas upon which rat abatement operations have been conducted.



Note: Data supplied by Board of Health, Territory of Hawaii

Graph by H. J. Spencer

Figure 14.—Graph showing monthly pregnancy fluctuation of female rats examined. Hamakua district, Island of Hawaii.

Species Ratio

As a result of numerous natural circumstances as well as various man-made conditions, the absolute and relative populations of each of the four species of rats over the Territory vary in almost every locality. There seem to be no definite criteria by which man can anticipate the presence or absence of certain species of rats in a given locality. Also, there are but very few factors that will explain the distribution of the rats in the varied type localities. Trapping records for the fiscal year have been summarized as to species of rats caught, given in table 30.

Table 30.—Rat species in various parts of the Territory of Hawaii, expressed as percentages of all rats caught in that region

Species	Hamakua	Kona	Maui	Oahu	Kauai
	Percent	Percent	Percent	Percent	Percent
Rattus norvegicus	6.3	1.4	.1	1.5	73.7
Rattus rattus	8.4	58.6	7.7	26.1	8.2
Rattus alexandrinus	27.1	18.6	18.6	62.4	.5
Rattus hawaiiensis	58.2	21.4	73.6	10.0	17.6
	100.0	100.0	100.0	100.0	100.0

On the Island of Lanai, the Norway rat predominates almost exclusively. During the last 20 months many thousands of Norway rats have been trapped in the pineapple fields, while a total of less than 50 of the other three species has been taken. The mongoose is absent on Kauai and Lanai. This information together with that in table 30 above has given rise to a theory that in the absence of the mongoose the Norway rat will kill off the majority of other rats. Where mongooses are present, the pugnacious Norway rat will fight the mongoose and invariably be killed, while other rat species will evade the mongoose by escaping into small burrows or by climbing. In such localities the mongoose probably does not reduce the total number of rats but does cause a shift in species type. Unfortunately, one must admit that this is only a theory which happens to agree with trapping records.

Food Preference

Stomach contents of rats caught in and about sugarcane fields on the windward and moist side of the Island of Kauai consisted of the following types and proportions of foods (table 31).

Table 31.—Stomach contents of rats, caught on the Island of Kauai during April, May, and June, 1937[1]

Type of food	Norway	Hawaiiensis	Black
Cane	60.09	26.00	.....
Coconut (trap bait)	14.86	52.00	17.70
Yellow foxtail seed	7.05	9.50	22.20
Guava	4.17	.....	22.20
Flesh	4.47	1.00	2.22
Insects	7.46	9.50	2.22
Berries	1.09	1.00	28.90
Grass seed and leaves	.52	.....	.....
Lantana	.29	1.00	4.44

[1] No *alexandrinus* rats were trapped during this period.

In the Kona district of the Island of Hawaii, a similar study was made covering each month of the fiscal year.

TRAP STUDIES

In any rat campaign, traps are necessary to catch live rats for laboratory studies as well as other types of traps to catch and kill rats in order to reduce the rat population. A trap made in Japan, efficient for catching live rats, is shown in figure 15, and can be purchased locally for $2.80 to $3.50 per dozen. Its valuable features are a noiseless action; sturdy construction for rats (mongooses are very destructive to any trap); a one-way entrance unit for additional rats attempting to enter the cage after the door is down; and a wire loop which is part of the door spring mechanism and can be used as a handle after the trap is sprung.

An official rat trap has been used almost exclusively for catching and killing rats in the rat abatement campaign. This trap is more efficient than another trap manufactured by the same company and previously used by Territorial agencies to a great extent in rat control operations. The two-way set-off trigger of the former is an improvement over the one-way set-off trigger of the latter trap. The wire hook for the coconut bait of the official trap is superior to the pan bait holder of the other trap.

POISON BAIT STUDIES

Studies have been continued to develop more efficient and cheaper poison baits for rats. The principal lethal agents have continued to be thallium and arsenic, although ground glass for a time appeared promising. These baits have been developed in the laboratory and after preliminary cage trial have been given further field trial. Table 32 summarizes all field trials to June 30, 1937.

Bait			No. of tests	Total baits placed	Total baits taken wholly or partly	Total average acceptance[1] of individual tests
Type	Attractant	Toxic agent				
		SAUSAGES				Percent
Standard	Bacon rind	Thallium	52	19,714	13,821	61.64
Emergency	Do	Do	19	4,268	2,587	60.07
Standard	Do	Arsenic	25	8,424	4,161	57.41
Experimental	Do	Glass	3	399	253	58.95
Standard	Hamburger	Thallium	47	15,599	11,680	67.47
Emergency	Do	Do	18	4,239	2,726	63.14
Standard	Do	Arsenic	27	10,198	6,599	52.73
Emergency	Do	Do	7	8,655	3,500	45.85
Experimental	Do	Glass	6	2,559	1,678	54.67
Experimental	Do	Red squill	3	299	236	83.45
Standard	Salt pork	Thallium	26	3,605	2,898	60.03
Standard	Do	Arsenic	38	10,216	5,686	50.51
Standard	Fish	Thallium	23	3,925	2,948	72.51
Standard	Plymouth squares	Do	7	1,951	1,255	72.80
Experimental	Pine bran	Do	1	152	127	81.93
Experimental	Blood	Do	3	399	250	54.10
Emergency	Do	Arsenic	3	399	250	54.10
Experimental	Do	Glass	3	399	239	56.42
		TORPEDOES				
Experimental	Rolled oats	Thallium	2	100	30	30.00
Experimental	Blood barley (plain)	Do	1	319	285	89.30
Experimental	Blood barley (corn oil)	Do	1	250	245	95.20
Experimental	Pine bran—blood	Do	5	893	202	20.69
Experimental	Pine bran—fish oil	Do	5	657	288	43.00
Experimental	Soy bean—blood	Do	5	1,084	518	42.79
Experimental	Soy bean—fish oil	Do	5	780	462	44.72

[1] Acceptance is a term used to indicate the percentage of bait piece eaten, 25 percent or more within 48 hours after placement.

Table 32.—Summary of all field tests on poison bait acceptance
July 1, 1936, to June 30, 1937

Table 32 shows clearly the acceptance of the poisoned meat rat sausages and grain torpedoes during the year as determined through observation checks of bait placements in the field.

Figure 15.—A very satisfactory wire trap for catching live rats (manufactured in Japan).

As a result of the maritime strike, which stopped all importation of rat bait ingredients for three months, island-available substitutes had to be used to a great extent in the baits produced during the period November 1936 to March 1937. The strike and the report of the seemingly increasing rat depredations helped influence the research laboratory in sanctioning the use of hurriedly prepared, unproved bait formulas for rat-control operations over the Territory during that period. Under normal conditions, only after a poison rat bait has been thoroughly tested and its acceptance and efficiency definitely established is a formula approved for general production.

In table 32, the various tests of numerous poison meat sausages and grain torpedoes are segregated under the three terms—standard, emergency, and experimental. The "standard" group includes all formulas which have been thoroughly tested and their acceptance

and efficiency definitely determined. The "emergency" group includes all formulas which were hurriedly concocted of inferior ingredients during the strike period when more efficient poisons and other bait materials were unavailable. The "experimental" group includes all formulas under trial in the process of development of better poison rat baits.

In practically every instance there is a marked difference in the acceptance of the standard and emergency formula groups of the same type attractant and poison. The standard thallium formulas consistently show a higher acceptance than do the emergency thallium formulas; likewise, the standard arsenic formulas have a higher acceptance than the emergency arsenic. The use of arsenic poison is an emergency measure in itself, as it has been found to be inferior to thallium as a rat poison in the Territory. It will be noted that arsenic formulas in either the standard or emergency groups are always lower in acceptance than the thallium groups.

Knowledge that poison rat baits are partially or wholly consumed by rats is not sufficient. We must have more direct proof that the rat population has been reduced. The method selected to obtain such proof is as follows: A rat-infested area is trapped for two or three successive days to get an index number of rats per acre. Poison bait is then broadcast over the area, which, five days later, is again trapped to get the new index of rat population. The reduction in number is credited to the poison bait and the percentage reduction is defined as "bait efficiency."

This method is not perfect. The initial trapping to establish an index removes a number of rats. Again, rat catches on successive nights are dependent on weather conditions. A later improvement has, therefore, consisted of placing poison bait over a large area, then trapping on the poisoned area and a nonpoisoned area simultaneously to obtain values for rat populations. Difference in populations is assumed to have been caused by poison bait. Such data for Kona and Hamakua occur in tables 33 and 34.

It has been generally proven that the meat baits have a greater attractiveness to rats than the grain torpedo over most of the rat-infested agricultural areas on which both types of bait have been tested. This is not to imply that one or the other of the two types of bait is recommended for exclusive use on these areas; on the contrary, it seems advisable to use the two types either simultaneously or alternately.

Poison bait[1] used	Area poisoned (acres and cover)	Check plat	Amount bait used	Date poison placed	Bait acceptance	Date trapping indexes—poison plat and check plat	Rats per 100 traps per day check plat	Rats per 100 traps per day—poisoned plat	Bait efficiency
		Acres	Pounds		Percent				Percent
100-T bacon rind, sausage	10 coffee 8 pasture and guava	4	50	May 19	—	May 25, 26, 27	23.33	19.44	16.67
202-T cracked barley-blood, torpedo	5 taro	5	30	May 21	—	May 25, 26, 27	29.44	5.00	83.02
202-T cracked barley-blood, torpedo	12 coffee	5	30	May 24	56.39	May 28, 29 June 1	21.66	8.33	61.54
300-T hamburger, sausage	22 coffee 3 taro 6 guava	5	95	May 7	—	May 15, 16, 17	20.00	17.42	12.90
400-T salt pork, sausage	28 coffee 8 pasture and guava	5	80	May 12, 13	49.83	May 19, 20, 21	19.46	8.20	57.86
400-T salt pork, sausage	14 coffee 3 corn 5 guava	4	90	May 20	68.27	May 25, 26, 27	33.66	11.46	65.94

[1] Thallium sulphate as lethal agent in all baits.

Table 33.—Poisoned bait efficiency tests
Kona, Hawaii

Poison bait[1] used	Location	Area poisoned (acres and cover)	Check plat	Amount bait used	Date poison placed	Date trapping indexes—check plat and poison plat	Rats per 100 traps per day—check plat	Rats per 100 traps per day—poison plat	Bait efficiency
			Acres	Pounds					Percent
202-T cracked barley-blood, torpedo	Kohalalele Gulch Makai	36 gulch-land	18	40	Apr. 1	Mar. 29-Apr. 1 Apr. 2-5[2] Apr. 6-9	16.4	Apr. 2-5[2] 6.6 Apr. 6-9 1.9	Apr. 2-5 59.6 Apr. 6-9 88.5
202-T fish oil, torpedo	Kohalalele Gulch Mauka	66½ gulch-land	2	81	Apr. 21	Apr. 16-21 Apr. 22-26[2] Apr. 27, May 1	8.0	Apr. 22-26[2] 3.8 Apr. 27, May 1 0.5	Apr. 22-26 52.5 Apr. 27, May 1 93.7
303-T hamburger, sausage	Kohalalele Gulch Makai	36 gulch-land	18	26	Apr. 5	Mar. 29-Apr. 1 Apr. 10-15	16.4	1.2	92.7

[1] Thallium sulphate lethal agent in all baits.
[2] Trapping and results during period of work of the poison.

Table 34.—Poison bait efficiency tests
Hamakua, Hawaii

More and more it is being found that odors accompanying the baits of either type are very important factors in the acceptance of the baits. It is practically an undisputed fact that rats and mice locate various morsels of food such as the poison rat baits through their senses of smell. Rats have been observed to pass by non-odoriferous rat baits without noticing them. On the other hand, rats have been watched making every effort to locate the origin of attractive food odors, and not until they followed the air currents carrying the food odors did they find the baits.

The above has been mentioned to explain, in part, the variation in the acceptance of the various types of bait in the above tables.

Manufacture and Transportation of Poison Baits

It was believed that poison bait could be produced more economically and under more adequate supervision in a central mixing plant. This policy made it necessary to overcome the problem of storage and transportation of meat baits to keep them in a fresh and enticing condition for rats. Sterilizing and canning the meat baits was attempted. Sterilization by cooking was feasible but this process changed the nature of some baits and lowered their attractiveness as compared with fresh baits. This experimental work is still in progress with trials of vacuum packing and use of mold preventives, sodium sulphite, and other agents.

On some plantations having cattle, daily home production of fresh meat baits from the poorest cattle will probably be economical. On other plantations where a supply of cheap labor is available, grain baits can be wrapped into torpedoes, probably by women. The rat laboratory of the station is now putting up grain baits in bulk which can be wrapped at their destination. The ultimate solution of where and how rat baits should be prepared has not been reached, and the rat laboratory continues to work on this and allied problems. Figure 16, below, depicts bait samples as prepared for shipment by the laboratory.

FIELD OPERATIONS

Oahu

Using the macadamia-nut orchard as a field laboratory, traps were placed for a time at every tree, and trapping continued over a period of nine months. Results obtained were:

Total rats trapped	1,781
Total mice trapped	457
Total trap days	177,814
Concentration—traps per acre	89
Total rats trapped per acre	99

Analyses of trapping results definitely indicated that many of these rats were coming into the orchard from surrounding waste land.

Kona

The coffee area in Kona consists of about 5,000 acres distributed among approximately 680 families. Rats damage the coffee by girdling the young fruit-bearing branches, mainly during Kona's dry season from December to June. About 500 acres of coffee have been severely damaged by rats.

Rat control operations were begun May 1936, and continued until June 1937. During 1936 the work consisted mainly in trapping with a small force to obtain data on sex and species ratio; analyses of stomach contents were made, and field tests were conducted with poisoned bait to test preference, acceptance, and efficiency.

In February 1937, a concerted poison campaign was started with poison bait spread through the coffee area. During the period February to June 1937, a total of 11,468 pounds of poison bait was spread over 13,913 acres. Thus a large part of the area could be said to have been covered three to five times. The bait most preferred by Kona rats was the hamburger-grain sausage, with thallium as the poison. Funds from the Kona allotment were expended by June 1937. The Kona farmers have participated in the rat campaign by spreading poison and by trapping with about 25 gross of traps loaned to them for an indefinite period. As a proof of the efficacy of this program, E. K. Nishimura, county agent, reports that the damage previously done by rats to the coffee industry in this district averaged $45,000 to $60,000 annually; he estimates the present damage to be only $10,000 per year.

Hamakua

In the Hamakua region on Hawaii, as on Maui, rat abatement work was under the direct supervision of the Board of Health. The program in this region of very heavy rat populations and presence of bubonic plague consists of rat trapping, rat poisoning, and a

Figure 16.—Poison rat baits are shipped in various containers: Sausage type baits are usually shipped in sealed cans, 30 pounds to a carton; bulk poisoned grain baits are shipped in paper-lined bags, 80 pounds to a bag.

small amount of removal of underbrush and cover. The gulches in this region are very deep and almost impenetrable to man. Statistics on operations for the fiscal year are given below. Figures are for the joint program financed by the Board of Health, Hilo Shippers Wharf Committee, sugar plantations, Works Progress Administration, and by Agricultural Adjustment Administration and Hawaiian Sugar Planters' Association funds disbursed through this station.

Trap days	2,356,887
Rats per 10 trap days	647
Rats trapped or killed	153,319
Mice trapped or killed	93,483
Mongooses trapped or killed	434
Poison bait distributed (pounds)	21,000

The above figures have been obtained from the Annual Report of the Board of Health of the Territory.

MAUI

On Maui, rat control has been practiced for years with a gradual lowering of rat population. In this more rolling area of small gulches, rat control has consisted mainly of trapping and of clearing rat harbors. Very little poisoned bait was used. The rat program on Maui is financed by the agencies shown below in descending order: Maui Agricultural Company, Works Progress Administration, Territorial Board of Health, Agricultural Adjustment Administration (through this station), U. S. Public Health Service, Hawaiian Commercial and Sugar Company, Maui Quarantine Tax Fund Commission, Hawaiian Sugar Planters' Association (through this station), Wailuku Sugar Company, and Kahului Railroad Company. All services and materials have been placed under the direct supervision of the Territorial Board of Health. Statistics for the fiscal year follow: (Spencer, Hansen, Jordan)

Trap days	1,498,615
Rats per 100 trap days	365
Rats trapped or killed	57,567
Mice trapped or killed	38,899
Mongooses trapped or killed	117
Poison bait (pounds)	1,047
Total acres gulches and rat harbor cleared	1,627

REPORT OF THE BRANCH STATIONS

KONA

The Kona Branch Station is situated in the heart of the coffee region. Continuing low prices for coffee have resulted in the abandonment of this crop by many marginal farmers. This station's program has shifted so that more attention is now paid to other crops which may supplant coffee and provide a new source of income for Kona growers. Macadamia nuts and taro appear most promising. Over 7,000 macadamia seedlings were grown at Kona last year.

The purchase of approximately 7 acres of land adjoining the branch station will provide area for seedling nurseries and experimental plats of other tropical fruit trees.

R. K. Pahau, the superintendent, spent a part of the past year in Honolulu taking graduate work in botany and horticulture.

HALEAKALA

Robert Lyman, a graduate of the University of Hawaii, 1935, has served as superintendent of the Haleakala Branch Station during the year. Principal activities have been the testing of many vegetables at this elevation (2,180 feet), and tests of various grasses. Results are covered under their respective headings in this report. U. S. D. A.-34 sweet corn is being tested at Haleakala.

The branch station's buildings were markedly improved by the enlargement of the barn and tool shed, and erection of a laborer's quarters.

LAND AND BUILDINGS ACQUIRED

The piggery of the experiment station has been enlarged by the construction of four additional pens at a cost of $866.95. Two new steel poultry houses, each with a capacity of 125 pullets, were constructed at a total cost of $481.

The Kona Branch Station, formerly having an area of 4.94 acres, has been enlarged by the purchase of 7.5 acres of land adjoining it at a price of $1,701.50. The new area was transferred to the University of Hawaii by Executive Order 758, dated June 28, 1937. The enlargement of the branch station at Kona will

permit experimental plantings of macadamia, taro, litchi, and other crops which appear promising for this region.

At the Haleakala Branch Station, the stable and feed barn was enlarged at a cost of $323.67 to provide space for an office and additional storage space for machinery. A workhouse having an inventory value of $140 was dismantled and the material used for building the addition to the stable and feed barn. A laborer's cottage and a washhouse were constructed with costs of $198.48 and $100.11, respectively.

PERSONNEL

Toward the close of the fiscal year, lack of funds made it necessary for a number of employees to sever their employment with the station. At the close of the fiscal year there remained 53 full- and part-time commissioned employees, as compared with 83 in 1936.

Additions to the scientific staff during the year consisted of the following:

Lyman A. Dean, Assistant Chemist, Soil Chemistry; Winston W. Jones, Assistant Plant Physiologist, Tropical Fruits and Nuts; Kazuo Kikuta, Under Scientific Helper, Plant Pathology; Robert A. Lyman, Superintendent, Haleakala Branch Station; Charles Maruyama, Farm Superintendent, University Farm; Francis M. Takashita, Under Scientific Helper, Marketing; James E. Welch, Junior Olericulturist, Truck Crops.

Separations from the scientific staff during the year consisted of the following:

George H. Akau, Jr., Under Scientific Helper, Taro Processing; Nathan F. Ambrose, Assistant Agronomist, Truck Crops; Leonora N. Bilger, Collaborator, Chemical Research, Tropical Oils; Frank Botelho, Foreman, Poultry Farm; Harold B. Cady, Marketing Economist, Marketing; Hung F. Choy, Minor Scientific Helper, Taro Production; Julius L. Collins, Collaborator, Plant Exploration; Oliver Crosby, Principal Agricultural Aide, Agronomy; Jack K. O. Dunn, Minor Scientific Helper, Fruits; Robert C. Eckart, Junior Biological Aide, Rat Abatement; Dorsey W. Edwards, Junior Chemist, Agricultural Chemistry; Thomas O. Frazier, Scientific Aide, Marketing; Harold N. Fujimoto, Minor Scientific Helper, Rat Abatement; Tai Hee Hong, Junior Scien-

tific Aide, Parasitology; Wataru Ishikawa, Assistant Biological Aide, Rat Abatement; Shiro Kanemaru, Junior Scientific Aide, Marketing; Jushin Kaneshiro, Junior Scientific Aide, Marketing; Gaston J. Ley, Chemical Engineer, Taro Processing; Morris M. Masuda, Junior Scientific Aide, Marketing; Yutaka Moriwaki, Junior Scientific Aide, Marketing; Torlogh D. O'Brien, Assistant Gardener, Horticulture; Fuyuki Okumura, Marketing Assistant, Marketing; John H. Payne, Associate Chemist, Biology, Taro Processing; James Allen Pearce, Minor Scientific Helper, Fruits; Ruth C. Robbins, Assistant, Foods and Nutrition; Yuki Sugai, Minor Scientific Helper, Taro Processing; Leonard E. Swanson, Associate Parasitologist, Liver Fluke; Toyo Takase, Minor Scientific Helper, Nutrition; Francis M. Takishi, Under Scientific Helper, Marketing; Robert W. Taylor, Assistant Biological Aide, Rat Abatement; Benjamin A. Tower, Assistant Poultry Husbandman, Poultry Husbandry; Howry H. Warner, Principal Marketing Specialist, part-time, Marketing; Charles L. Wilbar, Senior Medical Officer, Taro Nutrition; Carroll P. Wilsie, Agronomist, Agronomy; Peter Yap, Farm Superintendent.

In almost every instance these employees have found other employment. Some resigned from the station to accept more lucrative positions elsewhere.

PUBLICATIONS

Bulletin No. 77—*Some Fruits of Hawaii: Their Composition, Nutritive Value, and Use,* by Carey D. Miller, Katherine Bazore, and Ruth C. Robbins. 133 pages. Issued January 1936 and revised March 1937.

Circular No. 11—*The Gizzard-worm, Cheilospirura hamulosa, and Its Transmission to Chickens in Hawaii,* by Joseph E. Alicata. 7 pages. Issued January 1937.

Annual Report of the Station for 1936, by O. C. Magistad. 96 pages. Issued December 1936.

TECHNICAL PAPERS

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Whitney, Leo D., and Hosaka, E. Y.—New Species of Hawaiian Panicum and Eragrostis. *Bernice P. Bishop Museum Occasional Papers,* vol. 12 (1936) No. 5, pp. 3-6.

Whitney, Leo D.—A New Species of Trisetum and a New Variety of *Panicum imbricatum* from the Hawaiian Islands. *Bernice P. Bishop Museum Occasional Papers,* vol. 13 vol. 13 (1937) No. 16, pp. 171-173.

Whitney, Leo D.—Some Facts about Taro: Hawaii's Staff of Life. *Paradise of the Pacific,* vol. 49 (1937) No. 3.

Wilsie, C. P., and Takahashi, M.—The Effect of Frequency of Cutting on the Yield of Alfalfa under Hawaiian Conditions. *Jour. Amer. Soc. Agron.,* vol. 29 (1937) No. 3, pp. 236-241.

FISCAL STATEMENT

Financial support of the station is derived from five classes of funds. These are (1) U. S. Department of Agriculture for support of the Pensacola Street Station; (2) balances of sugar processing tax funds; (3) funds from Congress for support of State agricultural experiment stations (these include Hatch, Adams, Purnell, and Bankhead-Jones funds); (4) funds obtained from the Territory of Hawaii; and (5) special funds donated by persons and corporations to the University of Hawaii for special investigations or other purposes. Disbursements of the first two classes of funds have been through the U. S. Treasury Department, while the last three classes are disbursed by the Treasurer, University of Hawaii. Actual disbursements of funds during the fiscal year 1936-37 are shown in table 35.

RECEIPTS

	Regular federal funds	Federal Funds—Agricultural Adjustment Administration						
		Taro	Liver fluke	Rat Abatement	Truck crops	Feeds	Fruits	Poultry
Received from the Treasury of the United States	$12,066.00							
Balance from 1935-36		$24,141.00	$27,043.92	$77,201.44	$43,169.41	$59,417.63	$39,614.66	$24,621.87
Receipts from Territorial funds								
Balance and receipts from sales								
Total Receipts	$12,066.00	$24,141.00	$27,043.92	$77,201.44	$43,169.41	$59,417.63	$39,614.66	$24,621.87

DISBURSEMENTS

Personal services	$ 8,267.39	$15,106.36	$11,165.83	$58,585.68	$21,850.73	$24,040.96	$20,070.73	$ 8,728.81
Supplies and materials	746.59	1,593.15	1,534.66	8,836.46	2,639.58	2,423.02	2,283.50	2,107.13
Communication service	186.35	68.40		72.45	1.80	59.83		.75
Travel expenses		81.50	472.50	838.35	5,223.07	3,148.20	838.95	252.00
Transportation of things	41.00	22.53	82.88	136.16	164.94	85.36	59.42	51.98
Printing and publications			38.19	11.00				
Heat, light, water, and power	1,033.62	324.66	25.12	70.69			614.65	
Contingent expenses	55.40	102.86	126.48	158.36	465.24	267.33	143.26	94.00
Equipment	75.65	793.12	216.44	1,661.47	818.87	2,380.23	2,504.39	510.91
Buildings and land			500.00					
Washington expenditures	1,660.00	353.83	859.99	2,535.43	929.54	1,489.22	3,522.67	237.14
Unexpended balance		5,694.59	12,021.83	4,295.39	11,075.64	25,523.48	9,577.10	12,639.15
Total disbursements	$12,066.00	$24,141.00	$27,043.92	$77,201.44	$43,169.41	$59,417.63	$39,614.66	$24,621.87

(Continued)

Table 35.—Financial Statement 1936-37

RECEIPTS

	Federal Acts				Territorial		Funds donated		
							Rat abatement		
	Hatch	Adams	Purnell	Bankhead-Jones	Bankhead-Jones offset	Special	Maui	Hawaii	Total
Received from the Treasury of the United States	$15,000.00	$15,000.00	$20,000.00	$4,593.20					$ 66,659.20
Balance from 1935-36									295,209.93
Receipts from Territorial funds					$4,593.20	$19,125.45	$5,000.00	$5,000.00	33,718.65
Balance and receipts from sales						19,462.40			19,462.40
Total Receipts	$15,000.00	$15,000.00	$20,000.00	$4,593.20	$4,593.20	$38,587.85	$5,000.00	$5,000.00	$415,050.18

DISBURSEMENTS

Personal services	$ 9,561.43	$13,608.25	$14,983.13	$3,439.82	$3,360.00	$16,589.41	$4,817.66	$ 880.38	$235,056.57
Supplies and materials	3,010.49	576.09	2,097.87	321.85	825.13	8,898.85	163.08	1,953.73	40,011.18
Communication service			.25		50.10	340.45			780.38
Travel expenses		308.30	260.55	125.00	57.25	1,591.88			13,197.55
Transportation of things	155.11	5.01	16.04	7.85	38.05	254.50		21.77	1,142.60
Printing and publications	997.56					720.00			1,766.75
Heat, light, water, and power					30.05	1,586.81	1.00		3,686.59
Contingent expenses	10.56	9.25	52.25		85.50	2,195.80	18.26	24.60	3,809.15
Equipment	1,264.85	493.10	2,589.91	698.68	147.12	3,287.34			17,442.08
Buildings and land						3,122.81			3,622.81
Washington expenditures									11,587.82
Unexpended balance								2,119.52	82,946.70
Total disbursements	$15,000.00	$15,000.00	$20,000.00	$4,593.20	$4,593.20	$38,587.85	$5,000.00	$5,000.00	$415,050.18

Table 35 (Continued) Financial Statement 1936-37